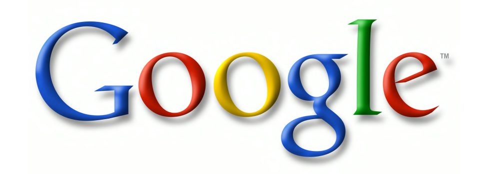


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J. C. Branner

THEORY

OF THE

EARTH,

WITH

PROOFS AND ILLUSTRATIONS.

IN FOUR PARTS.

By JAMES HUTTON, M.D. & F.R.S.E.

VOL. III.

EDITED BY SIR ARCHIBALD GEIKIE, D.C.L., F.R.S.

GEOLOGICAL SOCIETY,
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CONTENTS.

CHAP. VII.

CHAP. VIII.

CHAP. IX.

LIST OF ILLUSTRATIONS.

PREFACE.

THE illustrious author of the *Theory of the Earth* was born on the 3rd of June, 1726. After a life spent in active scientific research and prolonged reflection he was induced, when nearly sixty years of age, to prepare a concise account of the theoretical views he had been led to adopt regarding the geological operations of the globe. This essay was read before the Royal Society of Edinburgh in the spring of 1785, and appeared three years later in the first volume of the Transactions of the Society under the title of "Theory of the Earth ; or an Investigation of the Laws Observable in the Composition, Dissolution and Restoration of Land upon the Globe."

In the late summer of 1785 Hutton undertook a journey into the Highlands for the purpose of testing his views as to the origin of granite, and in later years he continued his explorations with the same object in other parts of Scotland. He had been urged to expand his essay, to include in it some account of the numerous observations which in the course of his busy life he had accumulated,

and thus to furnish the ground-work and confirmation of the theoretical conclusions which he had promulgated in perhaps too condensed and bare a form. At last, in 1795, he gave to the world his *Theory of the Earth, with Proofs and Illustrations*, in two octavo volumes. It bore on the title page that it consisted of "four parts." The first volume was entirely devoted to Part I, the second to Part II. The first chapter of Part I, consists of four sections, which are merely the four parts that constituted the whole of the first essay, and are reprinted with only slight additions. All the rest of the first volume, comprising two-thirds of it and the whole of the second volume, thus appeared as fresh material.

There is, unfortunately, no preface or preliminary sketch of the subjects as they were meant to be distributed through the several parts. We cannot therefore tell what portions of the theory were to be included "with proofs and illustrations" in the unpublished Vol. III. Playfair tells us in his *Biographical Account of Dr. James Hutton* that a third volume, necessary for the completion of the work "remained behind, and was still in manuscript." We learn also from the allusions of Lord Webb Seymour that this volume was "nearly ready for the press" (*Trans. Roy. Soc. Edin.*, vol. vii, 1814, p. 373). But up to the present time the work has never been given to the world.

A portion of the manuscript of this unpublished volume has been for more than forty years in the possession of the Geological Society of London. It forms a small quarto volume of 208 pages. The manuscript is that of an amanuensis, but here and there it is interspersed with notes or corrections in Hutton's own handwriting. Though the author had evidently read it carefully through, he allowed many inelegancies and obscurities of expression to remain uncorrected. These characteristics of his style have been preserved in the text.

The volume had evidently been lying some time unbound, for the first page (p. 139 of the MS.) has been soiled and torn, and has been repaired by the pasting of another leaf at the back. That the binding was done in Hutton's own lifetime may be inferred from his note on p. 209 of the MS. where he refers to this portion of the work as Vol. IV of the manuscript. If this inference be correct, it would thus appear that the first three chapters of Volume III of the *Theory* were bound up as three separate volumes of MS. and included at least 138 pages.

We can trace satisfactorily the history of the portion of the MS. now first published. On Hutton's death, if not before, it seems to have passed into the hands of his friend, commentator and biographer, Playfair. It is referred to and

quoted by Lord Webb Seymour in the paper which he wrote, in conjunction with Playfair, on Glen Tilt, and which was read to the Royal Society of Edinburgh on 16th May, 1814. It seems to have remained in the possession of Lord Webb Seymour until his death, when it passed into the hands of Leonard Horner, who placed the following memorandum at the beginning of the book.

"This MS. volume (part of a series) of Dr. Hutton's, with some additions in his own hand, containing six chapters of illustrations of his *Theory of the Earth*, was given to Lord Webb Seymour by Mr. Playfair (as Mr. Playfair himself told me), and after his lordship's death I received it from the Duke of Somerset when he came to Edinburgh on the occasion of his brother's decease.

"I give it to the Geological Society, to be preserved in the library, as an interesting document in the history of the science.—L. H. 30th Nov., 1856."

Efforts have been made to recover if possible the other volumes of the MS., but hitherto without success. It is difficult to form a satisfactory judgment as to the reason why the whole manuscript was not published a century ago. From various references in the following chapters, as well as from allusions in Vols. I and II of the *Theory*

we may infer that the MS. of Vol. III was nearly ready for the printer at the time when the first two volumes were given to the world. Hutton died in 1797, two years after the appearance of these two volumes. Playfair, into whose hands the MS. of Vol. III passed, outlived for twenty-two years the friend whose labours he so ardently appreciated and did so much to make intelligible and interesting to the world at large. We may be sure that some serious reason kept him from publishing the MS. which he had acknowledged to be necessary for the completion of Hutton's work. Possibly one cause of delay may be found in the want of some of the drawings which were required for the illustration of the text. These drawings were to be supplied by Hutton's friend and frequent travelling companion, John Clerk, of Eldin. If they were not all ready before Hutton's death there may have been a difficulty in procuring them afterwards, and thus time may have slipped away, until the death of Clerk, in 1812, made impossible the recovery of the drawings as they were originally intended to be.

The six chapters now published are mainly devoted to the illustration of Hutton's theoretical views regarding the origin of granite. Three of them deal respectively with the observations of De Saussure on the Alps, of Palassou on the Pyrenees, and of Dolomieu on Calabria. These include long

citations from those writers, with critical remarks by the author in the same style as in the previous volumes of his work. Of much greater interest and importance are the other three chapters, which contain narratives of geological excursions made by Hutton into different parts of Scotland in search of facts corroborating his theoretical views. One of these essays describes his famous visit to Glen Tilt. Another is devoted to an account of his journey through the granitic tracts of Galloway. The third contains a detailed description of the geology of the island of Arran.

These three chapters present the philosophical author of the *Theory of the Earth* as a diligent and enthusiastic worker in the field. He was reproached in his lifetime with being a mere theorist. It must be admitted that from none of his published writings could it be inferred that he possessed so remarkable an observing faculty as is revealed in his dissertation on Arran. This striking essay is a masterpiece of acute observation and luminous generalization. Had it been published in his lifetime it would have placed him at once as high in the ranks of field-geologists as he admittedly stood among those of the speculative writers of his time. It seems but a tardy act of justice to his fame that the merit of this practical side of his life-work should be now at last fully established.

The Council of the Geological Society has, at my request, undertaken the publication of the Hutton manuscript in the Society's possession, and has placed the editing of it in my hands. I have furnished such notes as seemed desirable in elucidation of the text; these are all enclosed within square brackets. I have likewise endeavoured to supply the place of the missing drawings, and for this purpose have revisited Arran with camera and note-book, following Hutton's route with his description in my hands.

The two published volumes of the *Theory* have neither an index nor a detailed Table of Contents. It is consequently a matter of time and labour to find in them the criticisms, generalizations, observations and references which they contain. I have thought that the index, made by me originally for my own use in studying this classic, may be found of service by others, and it is accordingly appended to the present volume.

It is a source of deep gratification to me to have been permitted to render a service to the memory of the father of Modern Geology. His views are chiefly known to the geologists of the present day in the brilliant exposition of them given in Playfair's "Illustrations." But his own writings, despite their acknowledged obscurity and prolixity, are well worthy of the careful study of all geologists who take interest in the philosophy of their science.

And I would fain hope that the present long-delayed publication of a portion of his third volume may be the means of directing renewed attention to his immortal work, which must ever remain one of the great landmarks in the onward march of Science.

ARCH. GEIKIE.

GEOLOGICAL SURVEY OFFICE,
JERMYN STREET, LONDON.

17th February, 1899.

CHAPTER IV.

Observations made in a Journey to the North Alpine part of Scotland in the Year 1785.*

IN Scotland there are two great tracts of mountainous country, each of which reaches from sea to sea, or occupies the whole extent of the island from east to west,

* [When Hutton's first sketch of his *Theory of the Earth* was read to the Royal Society of Edinburgh in the spring of 1785, he had never seen granite in place, save cursorily at Peterhead and Aberdeen. (*Theory*, vol. i, p. 214.) But in the late summer of 1785 he undertook the journey described in the present chapter, for the express purpose of searching for the junction of granite with the surrounding rocks. He gave a brief account of the results of this journey in a paper read before the Royal Society of Edinburgh on 4th January, 1790, and published in the third volume of the Society's *Transactions*. He refers to this paper in a footnote of vol. i of the *Theory*, p. 319, as presenting merely the general result of his observations, "which "will be given particularly in the course of this work."

at least in most places; therefore making some allowance, Scotland may be distributed into three parts or zones across the island;

The present chapter therefore probably contains the fuller account of these observations during the memorable visit to Glen Tilt of which his biographer, Playfair, gave so graphic a picture. We are told that when Hutton found a number of granite-veins traversing the dark schists in the bed of the river, "the sight of objects "which verified at once so many important conclusions "in his system, filled him with delight; and as his "feelings, on such occasions, were always strongly ex-"pressed, the guides who accompanied him were con-"vinced that it must be nothing less than the discovery "of a vein of silver or gold that could call forth such "strong marks of joy and exultation." (Playfair's *Works*, vol. iv, p. 74.) It will be seen that in his account of this journey into Perthshire, Hutton kept his eye as earnestly fixed upon the surface-features of the country as upon the relations of the rocks underneath. His narrative is therefore of great interest as showing his alertness of observation and the wide range of his geological interests.

If the narrative in the present Chapter is all that Hutton meant to publish of his observations in Glen Tilt, we may be surprised at its meagreness, considering the importance which he assigned to these observations in the establishment of his theoretical views as to the origin of granite. We need not wonder that his two

two of these are mountainous, stretching across the island in the direction of S.W. and N.E., and placed the one at the

friends and admirers, Playfair and Lord Webb Seymour, should have thought it of importance to ascertain the actual structure of the classic locality more precisely, in view of the controversy that had arisen between his followers and those of Werner. These two observers visited the glen in 1807, and Lord Webb Seymour, returning to it in the following year, prepared their conjoint memoir on "The Geological appearances in Glen Tilt," which was read to the Royal Society of Edinburgh in 1814. (*Trans. Roy. Soc. Edin.* vii (1816), p. 303.)

As stated in the Preface to the present work, Hutton's manuscript, now first printed, was in the hands of Lord Webb Seymour when he and Playfair prepared their conjoint paper, and occasional references are made in that paper to some of Hutton's unpublished observations in Glen Tilt and its neighbourhood. (*Op. cit.* pp. 306, 362, 364, 373.)

Another detailed account of Glen Tilt was read by Macculloch before the Geological Society of London towards the end of 1813, and was published in the third volume of the Society's *Transactions* with a good map and a number of excellent diagrams. The ground has been recently mapped by the Geological Survey and will be found in Sheets 55 and 64 of the map of Scotland.]

northern, the other at the southern extremity of that kingdom. Between these two regions, which are properly alpine, there lies a comparatively small extent which may be called low or champaigne country, as not being properly mountainous, but only interspersed with hills which may be considered as accidental, being neither formed of the general materials of the champaigne country, nor of the nature of the alpine hills.

It is the northern region of this alpine country which is now to be described; and we shall restrict ourselves to Perthshire, of which a map has been given from an actual survey.* In this district is to be found everything requisite for establishing a natural history, not only of this, but of every other alpine country.

It has been already observed that this mountainous region stretches across the island obliquely in the direction of the S.W.

* [No map accompanies the MS. As the account given by Hutton is not detailed, it has not been deemed necessary to add here a map either of Perthshire or of Glen Tilt.]

and N.E.; it is now only to be remarked that this general line which divides the north alpine country from the middle region, is preserved with a wonderful degree of regularity, in being nearly a straight line. But what is still more remarkable or worthy of attention is this, that the line in which the strata of this mountainous region are elevated or depressed, seems to preserve the same direction with this line of general division for the species of country; for while the perpendicular strata or edge-beds of this alpine region may be found inclined or heading both to the north-west and south-east, the general direction of S.W. and N.E. is still preserved in the stretching line of the strata which is horizontal; at least, this is the case much more frequently than it is otherwise.*

* [Hutton thus correctly noted that while the strike of the metamorphic (Dalradian) series of the Perthshire Highlands has a general persistent trend from S.W. to N.E., the dip of the strata may be either towards N.W. or S.E. He also observed that the trend of the Highlands as a whole coincides with the direction of the strike of the strata.]

The general composition of this alpine country, like every other, consists in alpine schistus* and granite. The granite is composed of various mixtures of quartz, feltspar, schorl and mica, and it is not regularly stratified in its structure, as is the other part of this alpine country. This stratified part therefore is in general termed schistus, not as determining its composing substance, but only the manner in which, from its stratified structure, it divides.

The alpine schistus, which is the most prevalent material of the Highlands, consists of micaceous slate, of granulated quartz, or quartzy sandstone, and of a composition in which either one or other of these prevails in various degrees, the micaceous schistus being often attended with garnets.†

* [Under the term "schistus," Hutton included not only what are now discriminated as "schists," but also all rocks associated with the schists and possessing a bedded character, such as quartzites and limestones. He also applied the same term to the highly inclined and contorted greywackes, grits and shales (Silurian) of the Southern Uplands of Scotland.]

† [The schists of the Southern Highlands consist

But besides these general beds, there are also found strata in which calcareous matter prevails; never, however, without some mixture and accompaniment of the general materials of the alpine country. All the limestone which I have examined appears to be perfectly sparry, and contains no vestige of organized marine body; it has always more or less of the siliceous and micaceous matter mixed seemingly in its stratification. The state of all those strata in general is to be extremely consolidated; and some of the siliceous stone is consolidated to such a degree

mainly of a varied series of altered sedimentary rocks, including different forms of mica-schist, clay-slate, schistose grit, graphitic schist, chloritic schist, granulitic gneiss, conglomerate, quartzite, limestone, and other accompaniments. With the metamorphosed sediments there occur numerous intrusive basic sills which now exist as masses of epidiorite, passing, where most crushed, into hornblende-schist. There are two principal bands of limestone, separated by a considerable thickness of different schists and quartzites. The "quartzy sandstone," mentioned in the text, is doubtless the fine granulitic quartz-schist or gneiss (Moine-schist) which plays so large a part in the composition of the Scottish Highlands.]

as that the component parts of its constitution are hardly to be distinguished.

But in some parts of the Highlands we have also a stratified granite; this is that which M. de Saussure has termed *granit feuilleté*.* It is evidently formed of granite materials and it is stratified along with the alpine schistus. This must be carefully distinguished as a different body from what may be called granite, or granite in mass, a body which has no stratification in its original constitution.

Thus the Highlands of Scotland, as well as the Alps of Switzerland, Savoy and other alpine countries, may be considered as composed of two things, mountains of schistus and mountains of granite. Some naturalists consider these mountains as being the primitive parts of the globe, or as having no origin from whence we may derive them

* [See vol. i, p. 314, where Hutton identifies the rock with the "gneiss" of the Germans. He knew of its existence in the Highlands from specimens, though he had not seen it there in place. Macculloch, when he studied Glen Tilt, thought that gneiss is a rare rock in Scotland. *Trans. Geol. Soc.* iii, p. 333.]

in the operations of the globe ; while others, here acknowledging a species of stratification, suppose them only to be primary in relation to other strata of which we certainly know the origin.* In this case of primary and posterior, naturalists have thought to distinguish granite as being the primary in relation to the schistus mountains which they thus suppose as having been formed posterior to it ; but as I have just now found evidence of the contrary in a journey which I have made to the Highlands, it will not be unacceptable to the public to know the state in which those things are found, and to be informed of the place where any naturalist, who is willing to be satisfied from his own examination, may have an opportunity of gratifying his curiosity, and perhaps discovering something interesting to science and useful to those philosophers who enquire into the origin of things.

Knowing that in the sources of the River

* [On the subject of primitive or primary, secondary and tertiary rocks, see vol. i, pp. 311, 320, 351, 360, 377, Playfair's *Illustrations of the Huttonian Theory*, pp. 11–13, and *postea*, p. 85, *note*.]

Dee there were great granite countries, and that in most of the sources of the Tay nothing is to be found but the alpine schistus, I considered the country between those two rivers as the most proper for discovering the relative state of these two bodies. Having also observed in the bed of the Tay abundance of gravel formed of granite and of porphyry, I doubted not of finding something of what I desired in the north-eastern branches of that river. Mr. Clerk of Eldin* and I being therefore on a

* [This warm and valued friend of Hutton's was a notable figure in the cultured society of Edinburgh during the last quarter of the eighteenth century. He wrote a well-known work on naval tactics, and was the first to suggest the method of breaking the enemy's line at sea, which proved so successful in warfare. He was likewise an accomplished artist, whose pencil was always at Hutton's service on their excursions in Scotland (see the Plates in vol. i). So great was the confidence which Hutton reposed in his judgment that, as Playfair tells us, Dr. Black and John Clerk were the only friends to whom he communicated the outline of his Theory of the Earth before it was presented to the Royal Society of Edinburgh (Playfair's *Works*, vol. iv, p. 50).]

visit to the Duke of Athol at Blair this harvest [1785], I expressed to his Grace my desire to examine the minerals of his deer-forest, and to visit the mountains from whence the granite rolling in the river came. The Duke willingly entered into our views, and Mr. Clerk and I being nobly supported by the most kind and hospitable assistance, made an agreeable party of pleasure of a thing which otherwise would have been incommodious and painful.

It is particularly in Glen Tilt that this most interesting part of natural history is to be seen. This glen is a long narrow valley, running in a straight line between two mountains, the sides of which are as steep as is possible for earth and stones to lie. The River Tilt that runs in this valley, discovers in many places the solid rock, which being cut or polished by the stream, presents here and there the most interesting picture or section of the strata. The direction of the valley for a long way is almost due S.W. and N.E.; the strata, therefore, which stretch in this direction, and present their edges in the bed of the river, are only

traversed either by the natural windings of the water-course in the valley, or by the irregularities of the strata themselves which are very subject to particular disorders.

On the south side of the glen, the strata are composed of alpine schistus, particularly of granulated quartz and micaceous limestone*; and these strata dip into the hill in descending to the south. On the other side of the glen, the steep face of the hill is all covered with lumps of beautiful red granite, not a particle of which is to be seen upon the south side.† Here therefore we are in the very spot which we desired, and fortunately for our researches, the river lays bare enough of the solid parts to give the most satisfactory view of what had been transacted in a former period, probably at the time the strata, which were originally horizontal, had been broken and displaced.

It must be recollected that the present question regards the granite, how far it is to

* [Quartzite, dark graphitic and other schists and the band of Blair Athole limestone.]

† [The granite forms an isolated mass on the right side of Glen Tilt below the Forest Lodge.]

be considered as a primary mass in relation to the alpine schistus; in that case, fragments of the granite might be found included in the schistus, but none of the schistus in the granite. But besides this point to be ascertained, I had in a preceding part of this work drawn a very probable conclusion concerning the natural history of granite, so far as those masses might be considered as analogous to basaltes, or subterraneous lava, in having been made to flow.* We have both those points now perfectly decided; the granite is here found breaking and displacing the strata in every conceivable manner, including the fragments of the broken strata, and interjected in every possible direction among the strata which appear. This is to be seen, not in one place only of the valley, but in many places, where the rocks appear, or where the river has laid bare the strata.†

* [See vol. i, p. 318.]

† Plate exhibits one view of this. It is immediately above the bridge at the Duke's Lodge.—[Note in Hutton's own handwriting.—None of the drawings that were to accompany vol. iii of the

Having thus ascertained this cardinal point, it was necessary to explore the solid mass of granite; for though it was evident this north hill of Glen Tilt must be granite, we had only seen the loose fragments with which, as well as with turf and soil, its face was covered. Having, therefore, with some difficulty, mounted the precipitous bed of a rivulet that comes from this long ridge of mountain, and which is fit for no other but the footsteps of a goat, we were rewarded with a view of the strata of the hill, being a perpendicular section across this ridge of mountain, the nucleus of which, or the internal strata, were the object of our search.

We first found the alpine schistus inclined as in the south side, and heading or rising

Theory of the Earth have been recovered. But the student will find some excellent diagrams of the Glen Tilt veins of granite in the memoir of Macculloch already cited. *Trans. Geol. Soc.*, vol. iii, Plates 13 to 22. A reduction is here given (Fig. 1) of Macculloch's Plate 18. That geologist admitted that "No drawing less in size than the rock itself could give an accurate representation of the place" (p. 265).]

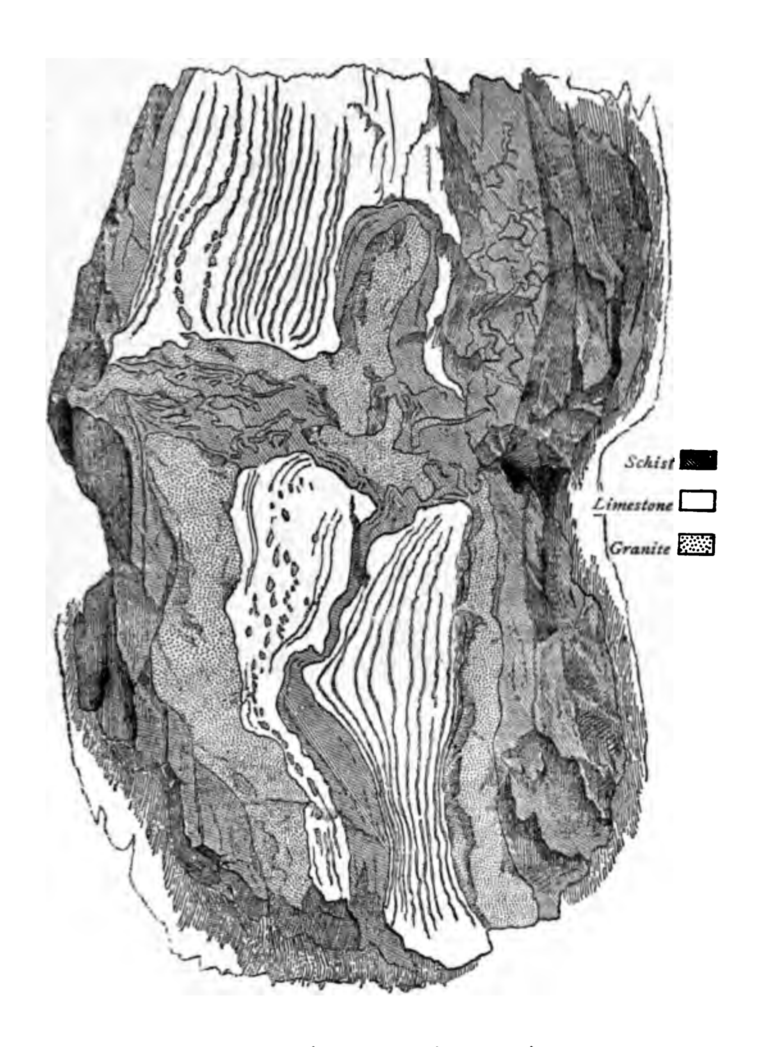


FIG. 1.—Granite veins traversing Schist and Limestone, Glen Tilt (after Macculloch, *Trans. Geol. Soc.*, vol. iii, Plate 18).

up to this north hill; immediately after which we found the granite under the alpine schistus seemingly bedded in like manner, and running parallel to the strata.*

In matters of science, curiosity gratified begets not indolence, but new desires. We now wished to see the extent of that granite which we had found; and whether it were one continued mass of granite to the River Dee, where perhaps nothing but granite mountains are to be found, at least where chiefly these abound. We had hitherto made the Duke's hunting-lodge in Glen Tilt our head-quarters. His Grace now proposed to remove us farther into the wilderness, and also to entertain us with the deer-hunting in his forest. We travelled up the Tilt, crossed the Tarf which runs into the Tilt, and came to the other hunting seat of Fealar, the most removed, I believe, of any in Britain from the habitations of men. Here we were near the summit of the country, where the water runs into the three

* [This paragraph is quoted from the original MS., by Lord Webb Seymour (*op. cit.* p. 364), who thought the stream here mentioned must be the Criny.]

great rivers Tay, Spey, and Dee. The Duke was successful in killing three harts and one hind, all in excellent condition; and our curiosity was gratified in finding both the granite and alpine schistus in this summit of the Highlands, between Glen More and Glen Beg.

The Duke's party proposed returning through the forest by the hills which are to the north of Glen Tilt, and we willingly accompanied them, as this was the chief part remaining to be surveyed. We walked up Glen Tarf, one of the highest glens in Scotland, running almost parallel to Glen Tilt, from whence it is separated by a ridge of mountains. Glen Tarf is upon a much higher level than Glen Tilt, for the water of Tarf, running from west to east, turns round at last to the south, and empties itself into the Tilt, which then carries this stream from east to west.

Upon the south side of this ridge, which separates these two parallel valleys of Tilt and Tarf, we have already seen that the alpine strata were at the bottom of the hill superincumbent upon the granite which

composes the body of the mountain ; here again upon the north side we found a similar appearance, so far as the strata discovered by the Tarf, though stretching east and west as usual, are reclined in the opposite direction to that in which they are found upon the south side of the mountain ; so that, as far as we may judge from this appearance, we ought to conclude that on the north, as well as on the south, side of this mountainous ridge the alpine strata are superincumbent on the granite mass.

But here we are to draw a very different conclusion from other naturalists, who, seeing the schistus on each side of this ridge of mountain, superincumbent on the granite, would necessarily conclude that the stratified schistus had been formed upon the granite, and in its present place. On the contrary, the schistus strata having been originally formed in a horizontal direction, the granite, certainly interposed among these broken and displaced strata, must be considered as posterior to those strata, notwithstanding that these are found superincumbent on the granite.

In this valley of Tarf we had also the satisfaction to find many tumbled stones, composed of broken schistus including granite ;* but this granite was in general different from that of Glen Tilt, which is the most perfect red granite I ever saw, whereas that here found is white. One of those pieces of stone had also this particular, of containing a vein which traversed both the mass of granite and broken schistus ; consequently here is the proof of another operation subsequent to the fracture of this schistus and the injection of the granite. Having mounted to the summit of this ridge which separates the Tilt and Tarf, almost everything we found was granite, and but little of the alpine stone.

From all that we have seen there is reason to conclude that the granite, though beginning upon the north side of the Tilt, is not continued without interruption, or mixture of the alpine schistus, to the granite country of the Dee, neither perhaps is it to be found in that district of the Dee

* [These words are quoted from Hutton's MS., by Lord Webb Seymour, *loc. cit.*, p. 362.]



without the intervention here and there of the alpine strata.*

Having observed that in Glen Tilt no vestige of granite was to be found upon the steep bank on the south side, but that on this side many pieces of porphyry were found, consisting of a grey or greenish ground, with spots of both white and red felt-spath floating in that ground, we ascended the hill, on this side of the glen, until we came to the precipitous rocks; here we found a bed of porphyry eight or ten feet deep, running parallel with the strata of alpine stone in the mountain. This was sufficient information with regard to that subject, for I had before discovered several beds of both grey and red porphyry

* [The recent mapping of the Geological Survey shows the general correctness of Hutton's observations. The granite on the north side of Glen Tilt is an outlying area of the same series of later eruptive masses which forms so much of the Grampian Highlands. None of this granite occurs on the south side, where, however, there are numerous veins, sills and bosses of schistose granite, felsite and other intrusive rocks. The metamorphic series is specially marked by quartzites, limestone, graphite-schist and other schists.]

in the woody dean within the policy, above the house of Blair; but as these beds of porphyry at Blair are perfect dykes and veins breaking and traversing the strata, and not running parallel with them, we have thus every satisfaction with regard to this subject that the nature of things admits of. We must therefore conclude that besides the granite which has been made to flow in breaking and displacing the strata of the alpine stone, there have been also masses of fluid porphyry interjected among those elevated strata.*

* This porphyry does not differ from granite in the substances of which it is composed, but in the manner of its composition. In the composition of granite the quartz and felt-spar, however variously proportioned, are equally mixed to form the stone, which then is composed of both, without the one appearing as a containing body, and the other as one contained. But it is otherwise in the porphyry; here is a ground more or less uniform in its nature, but always distinctly different from the spots or bodies floating in that ground which constitutes the porphyry.

The porphyries which we find here have grounds varying in their colours, from red to grey and greenish; but they have not much colour, nor consequently much



The general direction of those porphyry dykes being east and west, and from what Mr. Clerk had seen upon a former occasion, there being good grounds to find them traversing the bed of the Garry between Blair and Dalnacardoch, where this river runs in a trough cut in the solid rock and in a direction across the stretching of the

opacity. The spots or bodies contained in those grounds are distinct rhombic felt-spar, both red and white, and also some transparent bodies of crystal. Along with these are occasionally found small pyrites, black schorl, and in some of them calcareous sparks. The grounds of these porphyries are of a mixed nature, in which felt-spar must prevail, for they have some degree of fusibility; nor is this mixture uniform, for though completely solid, they do not admit of the most perfect polish.

[The foregoing note gives such a clear account of the rocks that the modern geologist has no difficulty in recognizing the petrographical types referred to. The pink rocks are varieties of quartz-porphyry which extend as apophyses from the more acid parts of the younger granites, while the grey or greenish rocks are lamprophyres, probably connected with the more basic (dioritic) portions of the bosses. Many of these lamprophyres show cavities that have been filled with calcite.]

porphyry, we set out upon this expedition, taking the falls of the Bruar in our way. We found among those cataracts a bed or dyke of porphyry; but being willing to pursue our chief object, which was the Garry, we proceeded westward; and there we had the satisfaction to discover no less than eleven or twelve of those porphyry dykes intersecting the strata, but sometimes so obliquely, that it is difficult to distinguish them from a parallel bed. Among these, those of the red ground prevail; and there are some which hardly deserve the name of a porphyry, as being little more than an uniform ground of red felt-spar or petuntze,*

* [A word applied by the Chinese to a form of the material (Kaolin being another) from which they manufacture their porcelain. In Stanislas Julien's *Histoire et Fabrication de la Porcellaine Chinoise* (Paris, 1856)—a work which was translated from the Chinese —it is stated that "the fusible part of the paste is furnished by a rock of a petrosiliceous nature, which, as well as the Kaolins, is found in commerce in the form of briquettes which are called pe-tun-tse." This word was for a time applied by mineralogists to a "fine, white vitrescible stone, compact and ponderous, and of considerable brightness when broken" (Williams,

without, or with few distinguishable spots. They are of various thicknesses, some of them 60 or 70 feet.*

Thus our alpine country consists of indurated or erected strata of slate, gneiss, and limestone, broken and injected with granite and porphyry.

Let us now compare those two regions of alpine country on the one hand, and that field of coal and marine strata on the other, which border together.

On the south side of the Grampians we have already observed that all the horizontal strata or flat beds are found broken and disordered by the injection of whinstone, trap, or basaltes, which is a species of

Natural History of the Mineral Kingdom, vol. i, p. 397). It seems to have been equivalent to the terms "petrosilex," "compact felspar," or "felstone."]

* [The traveller by the Highland Railway, as the train ascends the valley of the Garry between the stations of Struan and Dalnaspidal, may see from the carriage window some of these red porphyry dykes traversing the flagstones in the bed of the stream. They were briefly mentioned by Lord Webb Seymour (*op. cit.* p. 370) but without any reference to Hutton's observations in the MS.]

granite containing in general iron ore, and often calcareous spar.* In the alpine country again, the strata are broken and displaced by granite and interjected bodies of porphyry. These last appear to have been in as fluid a state as the basaltes, and to have been in like manner either interposed between the strata, in form of a bed, or interjected as a vein traversing them. The analogy of those two things is most remarkable, but the only conclusion which is here pretended to be drawn is this: *That whatever be the materials in those two cases, Nature acts upon the same principle in her operations, in consolidating bodies by means*

* [The author here refers to the Midland Valley of Scotland where the Old Red Sandstone and Carboniferous strata have been invaded by sheets and dykes of various basic igneous rocks (diabase, basalt, etc.). He believed the calcite observable in these intrusive masses to have been an original constituent of the rocks, and he actually cited its presence there as a proof of the former fusion of the basaltes under great pressure. (Vol. i, 79, 157; ii, 283. Playfair's *Illustrations*, p. 22.) The large part played by infiltrating water in transporting mineral matter in solution and depositing it in the crevices and cavities of rocks had not yet been realized.]

of heat and fusion, and by moving great masses of fluid matter in the bowels of the Earth.

We may now make some observations with regard to the operations of water upon the surface of this alpine country.

This alpine country of Scotland may be considered as a mass of strata elevated in their place and situation, being now, instead of horizontal, almost vertical; and inclined sometimes towards the north-west, sometimes again towards the south-east, though, in general, with some irregularity, heading north-west, and inclined about an angle of 45°. We are now to consider the effects of time and the influence of the water and atmosphere upon this mass of matter, which is in general composed of the most consolidated bodies, and of substances, the most indissolvable, the most hard, and consequently the most indestructible in their nature.

Where the River Tay breaks through the mountains below Dunkeld, the slate and alpine strata rise towards the south-east, contrary to the general elevation of these beds in that region. Westward again,

where the Almond breaks through the same ridge, the strata are almost vertical, but heading in a contrary direction to the north-west. In both those places, however, it is evident that the water has gradually, in the course of time, hollowed out a great gap of the mountain, through which the river has made its way, in wearing down the solid strata; for the very same beds are continued through the bottom and found in both sides of these stupendous gaps. We cannot have any measure of that quantity of matter which in such a course of time must have been removed from the tops of the mountains; but, in the height of the present mountain, we have a perfect measure of what has been removed in a later period of time from that mass in which we find this void.*

*[In the general account of river-action in vol. ii Hutton founded his conclusions on observations made by him in Scotland. And doubtless the river-terraces of the Tay, described above, supplied him with some of the examples on which he relied. (See vol. ii, pp. 205, 206, 210.) The well-marked terraces of the Tay have subsequently been fully examined and discussed by various geologists, in particular by Charles Maclaren. *Edin. New Phil. Journ.* vol. xxxv (1843), p. 276.]

At Dunkeld, the country is divided into the greater valley of the Tay, and the lesser valley of the Bran; but between those two, at the point of the promontory, there are the remains of an ancient plain, the surface of which is about 200 feet above the present level of the water. It is evident that the River Tay had formed this ancient plain, being perfectly horizontal, and having parts of a corresponding plain on the other side of the Tay. These plains, or parts of former haughs of the River Tay, are composed of rounded stones, sand and water-worn gravel; and I have found in this collection rounded stones which must necessarily have come from Glen Tarf and from nowhere else, being the mixture of the broken schistus with the white granite, which is common there, but the source of which I did not see.

Here we have evidence of the long succession of time upon this elevated country, and great operation of water, in wasting and wearing the materials of this high land, in forming the valleys between the mountains, and carrying an immense mass of matter from the summit of those

mountains into the sea. It must not be alleged that this is too great an effect for the operation of this river, which from the longest records of our history makes but trifling alterations upon its bed; neither must it be supposed that this had been the effect of some great catastrophe which may have happened to the globe; for everywhere, from the lowest to the highest part of this river, and all its various branches, the same observation is to be made, of parts of ancient water-formed plains remaining upon the sides of the hills, high above the present level of the running water. Neither is this all the evidence of this operation having been gradual, the work of time, and performed by the river in the natural course of things; for, not only here at Dunkeld, but all along the river and its branches, a succession of those plains is to be observed, one above another, seldom less than three gradations and sometimes four.*

In short, it is impossible to examine this river, and its many branchings, without

* [See vol. ii, p. 210, where this statement is made and the Tweed is referred to in illustration.]

being convinced that this district of the globe, as well as every other alpine country, has acquired its present form by the operation of water running upon the surface of the earth; that it has required an indefinite space of time to have hollowed out those valleys; and that the continual tendency of those operations, natural to the surface of the earth, is to diminish the heights of mountains, to form plains below, and to provide soil for the growth of plants.

CHAPTER V.

Observations made in a journey to the South Alpine parts of Scotland, in the year 1786.

HAVING last year got satisfactory proof of the Theory, from the examination of the north alpine region of Scotland, and having a more particular knowledge of the south alpine region, as I had often traversed it at different places, I was anxious to find also something decisive with regard to granite in this region, where I had hitherto seen but little of that substance. Accordingly, in harvest 1786, I set out with Mr. Clerk of Eldin, who now entered warmly into the investigation; and having in view to examine also the granite of Arran, we went by Glasgow. But finding it too late in the year for exploring the mountainous region of that island, we contented ourselves with

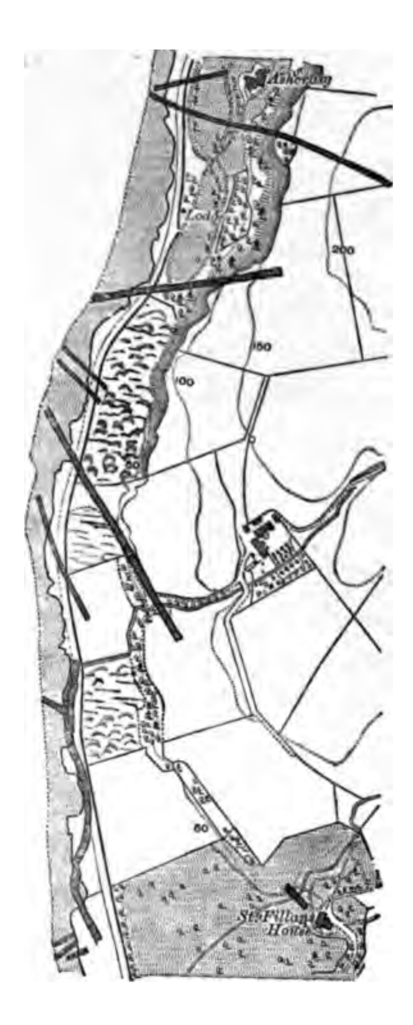


FIG. 2.—Dykes traversing Upper Old Red Sandstone, Shore, south of Skelmorlie, Ayrshire (from the maps of the Geological Survey on the scale of six inches to a mile).

making a circuit of the coast, from Glasgow round the shires of Ayr and Galloway.

In this tour, we had opportunity of observing the disorders or accidents of the coal and sandstone strata upon the coast of Ayrshire. These inclined beds or strata are not only broken and disordered by whinstone dykes, but also, are interspersed or interjected with concomitant bodies of the same kind. The dykes at Skelmorlie* are remarkable, a drawing of which is exhibited.†

I had only seen granite in three places of this whole southern region, viz., at Buncle Edge in Berwickshire‡ on the east, at Loch Doon in Ayrshire on the west, and Mount Criffel near Dumfries on the south.

* [These are referred to in vol. i, p. 153.]

† [In place of the lost drawing a portion of one of the sheets of the 6-inch scale maps of the Geological Survey of Scotland is given in Fig. 2. The dykes may be partly of Carboniferous, partly of older Tertiary date.]

‡ [This mass is traversed by the Whiteadder Water, a little to the north of Duns. (Sheets 33 and 34, Geol. Survey, Scotland.) It was examined by Sir James Hall and Playfair and is described in the *Illustrations of the Huttonian Theory*, § 296]

At Loch Doon, I had formerly seen the junction of the granite and the alpine strata, about the middle of the loch, where the granite and schistus countries joined; but here I only saw a small portion of the bare rock at the edge of the water on the west side, where the two bodies were closely united, without being possible to say which of these bodies was either uppermost or undermost, first or last. I was in great hopes of finding much of this junction upon the coast of the sea, where the agitation of the water and the attrition of the stones makes distinct sections of rocks, and gives an exhibition of nature most entertaining, as well as highly interesting to a mineralist; but I could obtain no certain information of the existence of granite anywhere in form of rock, although much of this stone in detached pieces, worn round by attrition or decay, is found both in the shire of Ayr and Galloway.

In going from Maybole to Girvan, we had whinstone hills upon the right, or to the west upon the sea-side; such whinstone, trap, or basaltic rock, as abounds with

pebbles or figured agates.* On the other hand, we had the alpine country† upon our left; and we were travelling upon the sandstone, marly and coal strata. All along this road, most of the large stones in the soil are round granite lumps, which certainly come from the granite mountains at the head of Loch Doon, in the border between the shires of Ayr and Galloway.‡

The coal and sandstone strata are to be found no farther than Girvan, where they terminate, and the schistus§ appears upon

* [Amygdaloidal andesitic and other lavas, forming a volcanic series intercalated in the Old Red Sandstone of that region.]

† [That is, the high Silurian uplands which rise steeply from the Girvan valley and stretch away to the north-east in a long line of heights.]

‡ [A prodigious number of blocks of grey granite has been carried from the granite mass at the head of the Girvan Water and strewn all over the lower grounds, down to the coast and westwards over the sea-floor. The granite source of these erratics forms a portion of the Loch Doon tract above referred to (*postea*, p. 41). An account of the Carrick boulders and their legends will be found in the Editor's *Geological Sketches at Home and Abroad*, p. 46 *et seq.*]

§ [This word is here applied to a series of greywackes,

the shore, in going towards Ardmillan Hill, stretching into the sea. After this the hills seem to be composed of a confused mixed rock; and then much whinstone of the porphyry kind, with green ground and white spots; some also of a red ground.* Upon the shore near Ballantrae there appear flattish inclined beds of a red sandstone, such as we had found along a great deal of the coast at Skelmorlie, but with this distinction, that whereas the Skelmorlie sandstone had sometimes strata of much quartz and other hard stone gravel, this at Ballantrae was alternated with many frag-

grits, sandstones and shales which have been thrown on end and considerably plicated and crushed. But they are not crystalline like the "schistus" of Perthshire; on the contrary, they contain an abundance of well preserved Silurian fossils.]

* [Hutton here alludes to the interesting group of igneous rocks in the Lower Silurian strata of the Southern Uplands. It includes lavas and tuffs, as well as intrusive masses of basic and acid material, and is well developed between Girvan and Ballantrae. He noted the difference between the red (Old Red and Carboniferous) sandstones of the north of Ayrshire and those of Ballantrae, Dumfries and Moffat, which have been referred to the Permian system.]

ments of the schistus, not rounded but angular. The same species of red sand-stone with the fragments of schistus and granite appears immediately connected with the alpine stone upon the other side of the schistus and granite country, at Dumfries, and it accompanies the high road all the way to Moffat, above which it terminates at the bottom of the schistus mountains. The hills above Ballantrae are whinstone, that one particularly upon which stands the Castle is composed of whinstone including other whinstone masses; and one would imagine from a superficial view of things here, as well as at Arthur's Seat by Edinburgh, that there had been volcanic eruptions; but from a more accurate view of things, this will appear to be the operations of subterraneous or unerupted lava, for it contains much calcareous matter in a sparry state.*

* [Hutton's observation of a "whinstone including other whinstone masses" has been confirmed by the Geological Survey. The rock, like that of Arthur's Seat, referred to in the text, is really a volcanic agglomerate, and indicates the site of an ancient

The second ridge beyond Ballantrae is composed of the true alpine stone or schistus much erected or on edge, rising to the north-west, and stretching south-west, as it commonly does; and this continues throughout all Galloway to Portpatrick on the one hand, and Dumfries on the other, except where it may be occasionally interrupted with granite, porphyry or whinstone.*

volcanic vent among the Lower Silurian rocks. It is interesting to remark that this agglomerate and that of Arthur's Seat had brought the idea of volcanic eruptions to the author's mind, and that he had not adopted this idea because he noted much calcite in the rock. He held the view that no superficially erupted lava could contain that mineral, which in his opinion was itself an indication of "the operations of subterraneous or unerupted lava." See the passages in the *Theory* already cited on p. 25.]

* [This "alpine stone or schistus" consists of a series of greywackes, grits, conglomerates and shales, with bands of chert, limestone and other subordinate layers, the whole belonging to the Silurian system, from the Arenig to the Wenlock and Ludlow groups. The strata have been thrown into innumerable folds, the axes of which range from south-west to north-east. The dip is generally at high angles, and as it is inclined towards the south-east over most of the region, the plicated

The Rinns of Galloway,* which now form a peninsula approaching to the coast of Ireland, appear evidently to have been at some former period of time an island between which and the main of Galloway the sea had flowed. The vertical schistus strata keep their general direction from the main of Galloway through each of the two lochs or bays of Ryan and Luce, as may be presumed, and are found in the same direction across this peninsula proceeding

strata are often inverted. These sedimentary rocks, which form most of the Southern Uplands, have been invaded by masses and veins of granite and other eruptive rocks, which may be assigned to the time of the Lower Old Red Sandstone. The prevalent dip and strike of the whole region were accurately noted by Hutton.]

* [The name given to the ridge of land which forms the western side of Loch Ryan and Luce Bay, extending from Corsewall Point to the Mull of Galloway, and connected with the mainland by the low tract of land at Stranraer. This connecting strip of low ground is covered with drift deposits, the removal or depression of which would allow Loch Ryan and Luce Bay to form one continuous sound. That this geographical condition formerly existed, as stated in the text, admits of no doubt.]

towards Ireland.* But after this gap had been made in the continued strata, between the Rinns of Galloway and the main of Scotland, there had been sand, gravel, and soil again deposited between this island and the rocky shore of Galloway, which thus have been again connected, as we see in the present state of things. We do not now enquire into this particular cause; perhaps we have not proper data to investigate this later change; and I only remark, in passing, that this appearance may perhaps be found to correspond with many proofs that are found upon the east side of Britain, ascertaining the higher level of the sea upon the land at a former period of time.†

* [The same Silurian strata are prolonged south-westwards under the sea and reappear with precisely the same characters on the Irish coast, from Belfast Lough to Carlingford Lough.]

† [Fragments of a raised beach, about 25 feet above sea-level, are to be observed round the shores of Loch Ryan, and also on those of Luce Bay, while in the centre of the low land, between the two inlets, a terrace or platform of sand and gravel, about 70 feet above the sea, probably marks an older sea-floor, perhaps belonging to the time when the Rhinns formed an island, as

All the rivers of Galloway, like that of Girvan in the shire of Ayr, appear to carry granite in rolling it from the higher ground. We therefore found blocks and tumbling stones of this substance more or less through all the soil in that country, and this was generally in proportion to the apparent facility of transportation by natural causes, from the more internal mountainous regions to the plains and sea-shore. We therefore concluded that there must be some great mass of granite in the mountainous part, as I knew there was at the head of Loch Doon, on the other side.*

suggested in the text. For Hutton's references to the proofs of uprise on the east coast of the country see vol. ii, p. 165.]

* [The transportation of boulders from the high grounds of Galloway has taken place on an extensive scale from the granite mountains. A vast mass of ice accumulated in the great upland basin south of Loch Doon, and streamed outwards in all directions. The portion that flowed northward and north-westward carried down the granite blocks to the Ayrshire plain and the Girvan valley. The mass that issued towards the south spread out over the lower hills, bore the boulders of granite into the Irish Sea, and carried those from Criffel eastward over the north of England.]

It is not many years since the people of Galloway have learned the proper use of granite in building. This stone from its uniform state, or equal structure, obeys the wedge; and thus the workmen, splitting the round blocks of granite dispersed along the surface of the country, prepare useful stones for masonry. They are therefore extremely well acquainted with this species of stone, which is sought after in the fields, and in some places has become an object of economy. But the constant information we received from these people when enquiring after rocks of this stone, was, that no such thing as this granite existed in the state of rock [*i.e. in situ*], and that nothing but loose blocks of it were to be found in all the country.

At Newton Stewart there is a lead-mine in which our friend Sir John Clerk is concerned; we had therefore occasion to converse with the company's overseer at this place. He has been everywhere in that country, and has examined the mountains in particular. I thought that here I should find proper intelligence, in

order to conduct our further route; but here I was disappointed. He had never seen any granite in rock. He had made some trials of veins upon the coast of Coend [Colvend], where I had expectation of meeting with the granite country of Criffel, a mountain to the south-west of Dumfries, which I knew to be of granite; and he informed me that those veins were not in granite. I have reason to believe his information just, as we found a change of rock to take place near Coend, but from the generality of his proposition with regard to granite, I could not help at that time distrusting this part of his information, as well as suspecting the accuracy of his observation.

Being thus left without any further guide than our general plan, we proceeded to coast the country, as taking a precognition of the field for our particular enquiry. We had not gone many miles from Newton Stewart, until we observed the most unequivocal marks of the vicinity of the granite country; this was the abundance of granite rolled in the rivers. Then

looking up towards the mountains, we observed one which corresponded perfectly with that idea; this is Cairns Muir [Cairnsmore of Fleet], a great round mountain, exposed immediately to view from that part of the road upon the coast.* Therefore being now determined, we put up our chaise at the village of Ferrytown,† and procured horses and a guide to conduct us through the muir in pursuit of the object which we had in view.

Directing ourselves to the south-west side of this mountain which appeared precipitous, and where the solid rock is bare, our satis-

* [Cairnsmore (*i.e.*, the big cairn or mountain) of Fleet rises to a height of 2,331 feet, and forms the western end of one of the three great granite bosses of Galloway. This particular boss extends eastwards to Loch Ken, a distance of about 10 miles, and has a breadth of about 7 miles. It has been protruded through the Upper Silurian grits and shales which it has greatly metamorphosed, converting them in some places into a garnetiferous mica-schist. There is another smaller boss of granite near the village of Carsphairn, which rises into the hill known as the Cairnsmore of Carsphairn.]

† [Ferrytown of Cree, now Creetown.]

faction was complete, in finding almost every means of information that we could desire. In approaching to this place, we had the pleasure to perceive detached pieces of rock composed of both granite and the common schistus of this country ; and in this composition it appeared that granite was the invading and the schistus the invaded body. Seeing also, that the opposite hill to the south was not granite, we had here every reason to expect to find in this place that junction of fossils which was the object of our research ; nor were we disappointed.

The appearance of the face of this rock, at a little distance, was that of stratification ; we therefore judged that here were the vertical strata of the schistus country in contact with the granite mountain. In this, however, we were deceived ; for what appeared a regular stratification, was found upon a close examination to be truly granite. Had we enquired no farther into the matter, and had no theory either to establish or to overturn, we might have come away in the full persuasion that here we had found granite stratified, in the same regular manner

as the vertical alpine schistus; but we were not to be thus imposed upon by appearances; at the same time it cost us a great deal of trouble fully to understand what we saw, or read the book which was so plainly open before us.*

To a naturalist nothing is indifferent; the humble moss that creeps upon the stone is equally interesting as the lofty pine which so beautifully adorns the valley or the mountain: but to a naturalist who is reading in the face of rocks the annals of a former world, the mossy covering which obstructs his view, and renders undistinguishable the different species of stone, is no less than a serious subject of regret. Such was our case, in viewing a mountain which seemed as if cut asunder in order to gratify our particular desire. Upon a former occasion, we had been fortunate in finding the critical part of the rock washed bare and clean by the attrition of water, sand and stones in the valley of Glen Tilt [p. 12]. It was for this

* [This district is contained in Sheet 4 of the Geological Survey of Scotland, and is described in the Explanation to that Sheet.]

reason that we wished to find the conjunction of the alpine stone and granite, either in the bed of a river, or upon the sea-shore; and here we had the most desirable section exposed to our view, and had nothing to do but remove the thin veil with which the mineral face of nature was disguised. It was not without much pains and labour that we thus proceeded to investigate what could not appear at the first sight; and it was not without some regret that we left so noble a section unfinished, or without a full delineation of an object so decisive in its nature and of such extent. We saw, however, enough to describe upon principle what we here had learned; and the farther prosecution of the subject could only be for the satisfaction of others, not our own.

The drawings which Mr. Clerk took upon this occasion may be seen in Plate .*

* [These drawings not having been preserved, the reader may be referred to Plate V, accompanying Sir James Hall's paper "On the Convolutions of strata, and their meeting with granite" (*Trans. Roy. Soc. Edin.*, vol. vii), which exhibits the relations of the eruptive and stratified rocks at the opposite or eastern end of the Cairnsmore mass of granite.]

If, notwithstanding the regular fracture or stratified appearance of this rock, the granite shall be found including the broken and disordered schistus of those mountains, no doubt will remain with regard to the formation of this compound mass, so far as it must be concluded, that it was not by stratification but by regular contraction, like the basaltic columns, that this particular appearance of the granite had been produced.* But this is truly the case; for though the general mass might be here considered as of granite, this did not hinder that in places there was as much of the schistus as of the including granite. In some places, insulated pieces of schistus appeared included with the granite rock; in other places again, the granite formed only veins which traversed the schistus in different directions. In short, although when at a distance, being truly deceived by the stratified or schistus-like appearance of the rock, I had entertained

* [The jointed structure of granite, here correctly distinguished from stratification, is well seen in some parts of the Cairnsmore granite, but is still better displayed in the Arran granite described in Chapter IX.]

the most flattering expectation of being gratified with the junction of those two bodies, it was not possible to conceive an appearance more perfectly calculated to remove every doubt, or to command belief, with regard to an operation which perhaps never can be seen.* This indeed was a

* [It is interesting to notice that Hutton here failed to observe one of the most convincing proofs of the correctness of his doctrine regarding the later age and intrusive character of the granite. He did not perceive that the strata around the granite have undergone a high degree of metamorphism, and that losing their ordinary sedimentary aspect, they become indurated, micaceous, and schistose, until they pass into true mica-schists. Sir James Hall, in his first examination of the junction of the Galloway granite with the surrounding strata (1788), does not seem to have been impressed by any difference between the sediments when adjoining and when distant from the granite (*Trans. Roy. Soc. Edin.*, vol. iii, 1790, p. 8); but in the more detailed study which he made of the ground some years after Hutton's death, he observed this difference, and in referring to the mica-slate next the granite, cited it as " a most notable indication of the action of heat. Since the granite by its local intensity has performed the very effect which Dr. Hutton ascribes to the general heat below, as acting upon the lower beds, and converting

verity of which I had been fully satisfied before; and I was now seeking that general approbation which the nature of physical truths requires, and which the unexceptionable experience of nature must procure.*

them into gneiss." *Op. cit.*, vol. vii, 1812, pp. 102, 107.]

* This summer (1788) Sir James Hall was at great pains to visit this country. He found the granite extend from the hill of Cairns Muir to the side of Loch Ken, an extent about ten miles by six. In all this extent he examined the junction of the granite with the schistus; he found the granite in many places forming veins and running into the schistus in form of dykes; he found it breaking, displacing and invading the strata, and enclosing fragments of the schistus; in short, having traced the boundary of this body of granite, he found many beautiful examples of the invasion, and the most satisfactory evidence of the granite having flowed among the broken strata of the schistus; and of this he gave a proper description to the Edinburgh Royal Society. [*Trans. Roy. Soc. Edin.*, vol. iii (1790), p. 8. As stated in the previous note, Hall subsequently published a fuller account with illustrations, and entirely confirmed his earlier observations. *Op. cit.* vol. vii (1812), p. 98.]

When I was at Cairns Muir in 1786 I supposed that this body of granite had extended to the granite country of Loch Doon; Sir James Hall has cleared up this

Being thus fully satisfied with that day's adventure we returned at dark to the village, and set out next day on our journey around the coast, knowing that nothing but the quartzy schistus was to be found in going by the military road over the Corse-o' Slakes.* We had travelled but a very little way when, not far from Cassencarrie, the granite suddenly appeared in two places by the roadside.† It here presents a similar appearance to the granite of Cairns Muir, so

point. We may now be assured that there are two granite masses in this alpine part of Galloway; and that they are separated or distinct, though perhaps at no great distance. [As stated by Hutton himself in the footnote on p. 61, there are three principal masses of granite, besides a number of much smaller bosses, viz., those of Loch Doon, Cairnsmore of Fleet and Criffel. There is likewise the important though less extensive mass forming the hill known as Cairnsmore of Carsphairn, and others appear further north on either side of Nithsdale.]

* [An old inland road through the moors from Creetown to Gatehouse of Fleet.]

† [Three small patches or dykes of granite traverse the Silurian strata to the south of Creetown (Explanation to Sheet 4 of the Geological Survey of Scotland, p. 18).]

far as it rises in rectangular blocks, or breaks in rhombic pieces. But it is only a little of it that appears; and had we not been so fully informed the day before, we should not have been able to draw any farther conclusion from this appearance, except that here was granite, the particular connection of which with the schistus we could not perceive. After this, we found no more granite, except in the tumbled pieces of the soil; and all the country was alpine schistus, some of which had the fibrous appearance, breaking in pieces like split billets of wood; this was particularly in rising the hill to leave the beautiful coast of Cree.

We had now travelled along the plain of Galloway, as it may be called compared with the mountainous region, and were approaching to Kirkcudbright, when we were unexpectedly entertained with the appearance of granite, in a small ridge running from north to south. We were better informed with regard to the nature of this granite ridge, when, descending to the valley of the river of Dee, we had an opportunity of examining the rocks washed bare upon the river's side.

This was immediately below Tungland Bridge, where these rocks form a sort of cataract or rapid, to which the high tides of this river ascend.* Here we had the pleasure of viewing a most beautiful plan and section of three porphyry dykes, crossing at the same time the edge beds of schistus and the river. The drawing which Mr. Clerk made of them represents this view. The largest of the three is fourteen yards wide. The ground of this stone is pale red; the spots white feltspath and green schorl. Above the bridge of Dee, which is six miles higher up the river, another of these porphyry dykes crosses the river and the strata; and between those two bridges there are about a dozen others pursuing nearly the same direction, but not going in straight

* [The western end of the great granite mass of Kirkcudbright breaks up into innumerable dykes and veins which traverse the Silurian greywackes and shales. They are well seen in the bed of the River Dee for some six miles above its mouth as well as on the hills on either side. They are shown in Sheet 5 of the Geological Survey of Scotland. The Explanation to that Sheet contains a succinct account of the geology of the district.]

lines; some of them are above 30 yards wide. On the high grounds to the south-east of Kirkcudbright, we perceived similar dykes running in the opposite direction or parallel to the river, which the others crossed; but as everything is here much covered with soil, I did not see distinctly their connection with the strata.

Being bent upon examining the coast between Coend [Colvend] and Arbigland, (where I knew that the coal and sandstone strata were to be found upon the shore, and where Criffel presented an immense mass of granite immediately within the land) we set out from Kirkcudbright, to travel a road which perhaps was never passed in a chaise before. We were not disappointed in our expectations, for we found the granite come in upon our left as we approached to Munches,* and to be twice alternated with the schistus when we arrived at that place.

* [The seat of the family of Maxwell of Munches, situated on the alluvial plain of the River Urr about a mile and a half south from the village of Dalbeattie. The granite boundary lies immediately to the west along the side of the valley.]

Here our friend Mr. Maxwell gave us all the assistance in his power, but the junction of those two species of stone was covered from our sight; and we now entered a country of granite which, though low, is continued to the mountains of Criffel, and from that terminates about New Abbey near the River Nith. But this granite country does not reach the sea-shore upon the west, at least we found the schistus here intervening. There is a millstone quarry at Coend; the stone of that quarry is composed of sand, gravel and broken stones; I saw those millstones at Kirkcudbright, and did not visit the quarry, having other business to pursue.

The road from Coend Kirk, if it may be called a road, leads to a little sandy bay of the sea, just within the limits or entry of the Solway Firth.* Here it is common to ride along the sands when the sea has ebbed, in leaving the shore and making to Saturness [Southerness] Point near Arbigland, whither we were bound.

* [Probably Sandyhills Bay, at the little watering-place called Douglas Hall.]

The road was this way nearer, easier, and far more expeditious; but this was not our object; for now the rocky shore appeared, and we had every reason to expect to find something interesting in this critical spot. We therefore left the chaise, which we had for a long way attended on foot, to find its way up the hill, while we ran with some impatience along the bottom of the sandy bay to the rocky shore which is washed by the sea, it being then low water. We saw the schistus pretty erect, but variously inflected, as is usual, upon our right, where the land terminated in the sea.* Upon the left again, we had the granite appearing through the sandy shore; and above, the granite hill seemed to impend upon the erected strata, if these reached so far into the land. We saw the place nearly where the granite and the

* [The Upper Silurian strata of sandstone, grit and shale extend along the shore for about two miles east of Sandyhills Bay, much traversed by dykes and veins from the granite, which rises immediately inland into the group of hills that stretch from the Water of Urr to the mass of Criffel. The sedimentary rocks have been considerably altered from their normal condition—a change which, here too, Hutton did not detect.]

schistus upon the shore must be united; but this place was bushy; and thus our fears and expectations remained for a moment in suspense. But breaking through the bushes and briars, and climbing up the rocky bank, if we did not see the apposition of the granite to the side of the erected strata so much as we would have wished, we saw something that was much more satisfactory, and to the purpose of our expedition. This was the granite superinduced upon the ends of those broken strata or erected schisti. We now understood the meaning of the impending granite which appeared in the hill above this place; and now we were satisfied that the schistus was not only contiguous with the mass of the granite laterally, but was also in the most perfect conjunction with this solid rock which had been superinduced upon the broken and irregular ends of the strata.

But even this view of things, decisive as it was, did not fill up the measure of our satisfaction, which was to be still farther gratified with the only possible appearance which could now remain, in order to complete the

proof with every species of evidence which the nature of things could admit of. For here we found the granite, not only involving the terminations of the broken and



FIG. 3.—Intrusion of granite (paler parts) into altered Upper Silurian grits and shales. South side of the Criffel granite mass, Southwick, Kirkcudbright. (Explan. Sheet 5, Geol. Surv. Scotland, p. 28.)

elevated strata, but also interjected among the strata, in descending among them like a mineral vein, and terminating in a thread where it could penetrate no farther. Mr.

Clerk's drawing,* and a specimen which I took of the schistus thus penetrated, will convince the most sceptical with regard to this doctrine of the transfusion of granite.

Besides this appearance in which the complete investigation with regard to the nature of the superincumbent granite is made, we found these vertical strata of schistus traversed in different directions by two great dykes. One of them, which runs pretty much in the direction of the strata, is composed of an uniform red porphyry or petuntze, without spot or visible mixture of any kind; the other, which traverses them irregularly, may be properly termed a granite-porphyry, as having in general a distinguishable ground, but in other respects a perfect granite.†

* [In lieu of this lost drawing a representation (Fig. 3) of the relations between the granite and surrounding strata has been redrawn from the Geological Survey Memoir (Sheet 5, p. 28).]

† [The granite assumes various contact-forms along its margin, and from this peripheral portion dykes, veins and threads have been protruded into the strata, which have a general sea-ward dip away from the granitic intrusion.



Having climbed up the hill to the high road, we travelled along the side of the hill, above the steep bank which had formerly been made by the wasting of the sea, or the wearing of the rivers; here we descended occasionally in the ravines made by the water running from the surface of the hill. In those places, wherever we could see the solid rock, we found every confirmation that could be desired, of those appearances that have been now described, that is to say, every species of mixture and interjection of granite and porphyry among the broken and distorted strata.

Upon the whole, we may now conclude, that, without seeing granite actually in a fluid state, we have every demonstration possible of this fact; that is to say, of granite having been forced to flow, in a state of fusion, among strata broken by a subterraneous force, and distorted in every manner and degree. The most beautiful example of this operation is to be seen in the bed of the river of Glen Tilt (p. 13); and it is now

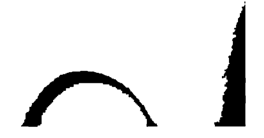
The main body of granite descends to the edge of the shore in several places.]

confirmed by this investigation of the subject which has been made in the south alpine region of Scotland.*

I have been the more anxious upon this subject, as I was long doubtful with regard to granite; not if it were an original body

* We have thus in the two counties of Galloway, or the county [of Wigton], and the Stewartry [of Kirkcudbright], three [principal] separate masses of granite, the one at Loch Doon, the other at Loch Ken [and Cairnsmore of Fleet], and the third at the mountain of Criffel near the coast of the Solway Firth, and extending from that west to Munches. [In actual fact, the Criffel granitic intrusion, with its associated porphyrite dykes and tongues, extends from the mouth of the River Nith south-westwards to beyond the bed of the River Dee at Tongueland—a distance of about 20 miles. It is some 6 miles broad at its north-eastern end, gradually diminishing towards the opposite extremity.]

We may here observe, that although granite is generally found in the most alpine part of a country, yet it is not always found, neither in the centre nor most alpine part. We have an example of this in the most centrical and alpine part of the Tweeddale and Annandale mountains; one would naturally have expected granite about the mountains of Queensberry and Hartfell; yet no such thing is found in that part of the country. [The next bosses of granite beyond those of the Spango Water and Nithsdale lie far to the north-east in



inscrutable to human wisdom, for it was always evident to me that it was a body formed by the operations of the globe, or according to the laws of nature which we may investigate; but I was uncertain if granite should be considered as a stratification of matter collected at the bottom of the sea, and afterwards consolidated by fusion in its place, or if it should be considered as a mass of subterraneous lava, which had been made to flow in the manner of our whinstone or basaltes. I was also anxious to put this subject in a clear light, as naturalists have been so generally of the opinion that this body should be considered as original, and as the solid nucleus of this Earth. They have been led to this conclusion, not indeed without some reason or probable appearance, but surely without sufficient ground for a conclusion of such magnitude in the natural history of this globe.

Cockburn Law, near Duns, and in the valleys of the Fassney and Whiteadder Waters traversing the heart of the Lammermuir Hills. The granite of these hills is referred to at the beginning of this chapter (p. 33 and note).]

I have now only further to add, that I do not pretend to say there is no stratified granite, or granite which deserves the term of stratification, from the manner of its original composition, as apparent in the present structure of the stone. I believe, on the contrary, that such strata may be found, and are even common in the alpine countries. I have from the country beyond Fortwilliam, on the way to Strontian, samples of this species of granite. It is striped, consisting of beautiful red, dark, micaceous, and lighter greenish strata. It is perfectly consolidated, much implicated, twisted or waved, in the manner of the alpine schistus, with which it is accompanied, and into which it graduates.* Here are more than five computed miles where this

* [Reference is doubtless made here to some of the varieties of gneiss and granulitic schists which form so large a part of the structure of the Highlands west of the line of the Great Glen. Some of these rocks contain thin leaves of granitic material, as if this had been introduced into them along their laminæ (*lit par lit* intrusion). They are traversed by younger masses of granite in which no trace of foliation or orderly arrangement of parts is to be observed.]



stone forms the strata. This I have from information, not having been there myself.

With regard to the stratification of granite, it is to be observed; that as the alpine stone in general consists of quartzy and micaceous particles, and as nothing further is required for the composition of granite, besides the admixture of feltspath with these materials, wherever this sparry* substance is found in the composition of the alpine strata, such stone must be considered as granite, so far as respects the composition, whatever distinctions may be made between such a consolidated stratum and a mass of granite which had been made to flow, and where the marks of stratification are extinguished. Now, that there should be indefinite mixtures of feltspath in the composition of the alpine strata, must appear most natural, when even in the common sandstone of the coal

* [This word was used by Hutton to denote the internal crystalline structure of a rock where the crystals or crystalline particles are readily perceptible and are interlocked so as to produce a firm compact spar-like mass, see vol. i, p. 25.]

and limestone countries, many particles of feltspath are to be found; for example, in that great bed of [Millstone] grit or sandstone in Derbyshire, which is superincumbent on the beds of limestones and cherts which contain the mineral veins. But it must be evident, that were the definition of granite to be taken from its massy state, or the negation of a stratified structure in that mass, then every other composition of this kind which should be found with stratification, must be distinguished by some leading feature in this compound stone. Still, however, the substance or materials are the same in all those different fossils, however they may be termed granite, porphyry or petuntze; and still the intention of nature will be found to be uniform, in producing rocks of various degrees of hardness and durability, yet all decaying for the purpose of this Earth in forming soil.

Before leaving this subject,—the vertical strata of our mountainous regions,—I would wish to make some observations, in comparing the south and north alpine parts

of the country with a view to put the operations of the mineral regions in the clearest light. For this purpose, we shall first endeavour to show in what respect these strata of the northern and southern regions differ, and then in what they agree.

It is not every specimen from these two different alpine regions that may be distinguished; but in general, it is easy, upon the first inspection, to say from whence most of the samples of these strata came, or to tell the country to which they belonged. In the northern regions, the predominant materials are mica and granulated quartz.* These are mixed in all proportions, and are seldom found absolutely destitute of each other. But it is particularly the granulated quartz-stone which constitutes the distinguishing mark of the north alpine schistus.

Mica, which is so general to all sandstone strata, is also found constituting a part of the south alpine schistus, but not so abundantly or in so visible a form as in

* [Granulitic mica-schist, "Moine-schist," quartzose flagstone or gneiss.]

the north alpine region. But as it is from the harder part of its composition that we have distinguished the northern schistus, we shall now in like manner distinguish the southern, by means of the analogous part of its constitution. It is therefore the hard stone of those southern schisti which is now to be compared with the granulated quartz-stone of the north.

When one has described a stone by granulated quartz, every mineralist understands the definition, although the chemist perhaps might find it difficult at least, if not impossible, to distinguish the substance of this stone from that of a certain sandstone, which, to the eye of a mineralist, might also be easily perceived as different from the other. Now it is just in this that I would place the distinction of these two alpine strata, which we now compare. The siliceous granulated substance of the northern schisti is quartz, and, having said this, we confess our ignorance of the natural history or preceding state of this substance; we find it is quartz, but as we know not how quartz has been formed, we know not

whether in its former state, when collected in the stratum, it had been common sea-sand, or grains of that pure substance which we term quartz. This, however, is not the case with regard to the siliceous substance which had been deposited in forming the south alpine stone; this is evidently sand and gravel, that is, fragments of hard siliceous bodies of various kinds, worn by attrition, and collected together by means of water.*

Here then is an important difference between these small composing bodies in

* [Hutton acutely distinguishes between the granulitic schists and flagstones of the Highlands and the grits and greywackes of the Southern Uplands. As regards the origin of the former he confesses his ignorance, and it must be admitted that a similar confession might perhaps still best express the knowledge of modern geologists on the subject. He is certain, however, that the strata of the south are hardened sediments, and he proceeds to reason from their analogy to the rocks of the north. The schists of the Highlands, east of the Great Glen, consist for the most part of altered sedimentary materials; but some parts of them, as well as much of the rock to the west of the Great Glen, still present many unsolved problems in regard to their origin and structure.]

the strata of the south and north regions. We are informed with regard to the former state or natural history of the one, but we are ignorant with regard to the other. But if the analogy between those two things, in all other respects, shall be found complete, we will then have a right to form some conclusion concerning the natural history of those bodies of which we were ignorant; and this conclusion, if not strained beyond the bounds of its legitimate principles, will afford sufficient conviction for all the purpose for which it is to be assumed.

But before proceeding to the analogy of the strata in these two countries, let us mention another small difference that may be observed. We have now considered the harder parts of those two stratified countries we may therefore compare the softer species, in order to see if we can find any material distinction sufficiently general to characterise those strata of the south and north.

I will not pretend to say that there is any absolute distinction between those softer schisti of the north and south, but I think there is a clear distinction of degree at least,

or of more and less in the composition of those softer strata; it is this—

In the northern schisti, the pure micaceous matter abounds; it is clearly micaceous, and it is in general pure or unmixed with argillaceous matter, by which it might be disfigured or concealed. It is just the reverse in the southern region; there the schisti in general, I mean the softer kind, abound in argillaceous matter, which occasions a striking difference in the appearance of the stones, more than really exists when they come to be examined more accurately.*

There is also another remarkable difference in the superficial appearance of these

* [The comparison here made is between the more micaceous schists of the Highlands, where the quartz becomes subordinate, and the shales interstratified among the sandy strata in the Silurian series of the south. It is recognised that in the former, the mica is much more definitely and abundantly present than in the latter, where the mica flakes are often hardly distinguishable amidst the argillaceous sediment. In the Highland schists the mica has been developed by metamorphism out of materials which, no doubt, were originally in large measure sediments; in the Southern shales, where the mica is derivative, it occurs only as small

two countries, which, as it arises from the same cause, may now be spoken of; neither will it appear impertinent in this place, as it illustrates the general theory of soil being formed from the decomposition or resolution of the solid strata, and as the different natures of those strata may be thus exemplified.

The hills of this country are commonly distinguished as either green or black hills. The one are covered with grass, the other with heath. According, therefore, as one or other of those two species of plants prevails, the mountain may be distinguished with the term of green or black. But the growth of these plants depends, *ceteris paribus*, upon the greater or lesser fertility of the soil, and this fertility depends upon the marly substance in the solid strata, from the resolution of which the soil is formed. But this marly substance, which procures fertility to the soil,

scattered plates diffused through the sediment. But in some of these shales, which have undergone a certain amount of alteration, especially round the granite bosses, much mica in minute forms has been produced out of the clastic sediment.]

may be considered as principally depending upon the argillaceous earth; and this would appear to abound most in the strata of the south alpine region. Let us now see how far the appearance of the vegetable surface of the country in those two regions will correspond with the conclusion which is naturally deduced from these examples.

If the north country consisted more of the green hills than the south country, appearances would here be found not to correspond with the theory; if, on the contrary, it is the south country in which the green hills are most generally found, and the north in which the black hills more generally prevail, we may be allowed to attribute this to the more argillaceous nature of the soft decomposing schistus of the south country, and the more pure micaceous schisti of the north. But I think there can be little doubt with regard to this matter of fact, which, however, is more immediately concerned with the economical views of man, than with the physiological history of this Earth; and though in each of these countries variety of soil and produce is to be observed, the green ground may be

said to prevail in the south, and the black in the north.*

We now return to the similarity of the north and south alpine schisti.

The strata in those two different regions may be compared in several respects; first,

* [The green aspect of the Southern Uplands, due to the spread of grasses over the decomposed surface of the Silurian shales and greywackes, has been much extended during the present century by the constant burning of the heather for the increase of the pasturage. In that region the naked rock comparatively seldom comes out in crags and scars, but crumbles into screes and soil, and forms, therefore, smooth-sloped, round and somewhat featureless hills. The "black" colour which Hutton attributes to Highland mountains may be ascribed to two causes:—the abundance of bare rock which often becomes crusted over with a dark weather-stain of confervoid growth, and the prevalence of dark heath and black peat between the projections of naked stone. While it must be admitted that hills as green as those of the south are to be met with in the Highlands, and that much of the most characteristic scenery of the north, though sombre in colour, can hardly be appropriately called black, Hutton's sagacious generalisation indicates the more metamorphosed and crystalline structure and less decomposable nature of the Highland rocks as compared with those of the Southern Uplands.]

with regard to their matter and composition; secondly, their inclination, and thirdly, their direction. These we may now examine in their order.

With regard to the matter of which they are composed, we have already considered this subject, when endeavouring to distinguish the south alpine strata from those of the north. We found no essential difference between those two things, although a proper distinction had been made; the materials and composition of both are of the same nature; they differ in some small respects, or only in degree; and though the original of the one is much more evident than that of the other, everything will tend to show that with regard to all essential points, they have been perfectly similar. This will appear more evident in examining the inclination of those strata.*

* [The detailed study of the Perthshire and Eastern Highlands (with which Hutton was most familiar), has abundantly proved that the schists of that region have been produced mainly from the metamorphism of shales and other more or less argillaceous strata. The intrusive doleritic sills have been extensively changed

All strata have been formed originally horizontal, or nearly so; this is a principle which I believe will hardly be disputed. Now if the alpine strata were found displaced with regard to their horizontal position, while all the rest of the strata of the Earth were in this respect unchanged, here would be a clear distinction, which might be considered as an essential difference. But though the alpine strata of the globe do not in this respect differ essentially from the rest, they differ in degree; in like manner as the hills are more elevated and inclined than the plains.

The original position of strata is horizontal; the most extreme diversion from that natural state is the vertical situation; therefore the medium degree with respect to this change is an inclination of 45°. We may be now able to form a distinction between the horizontal and the vertical strata of the Earth, or those of the plains and alpine regions. The strata of the plains

and hornblende-schists. The siliceous sandstones remain as quartzites, and the limestones have become crystalline marbles.]

are in general inclined beneath the medium degree; those of the alpine regions are generally above it. Therefore although, strictly speaking, there are no plains nor horizontal strata, both these terms are eminent distinctions, in relation to mountains and their vertical strata, with which plains and horizontal strata are contrasted.

Having thus considered what belongs to alpine regions with respect to inclination of their strata, we have only further to observe, that the two regions of this kind now compared are absolutely identical, no human observation, I believe, can find a difference.*

* [The disturbances which the metamorphosed rocks of the Highlands have undergone differ in no essential respect from those that have affected the Silurian strata of the Southern Uplands. This identity of structure is well illustrated by the coast-sections of Banffshire on the one hand, and of Galloway on the other. In the Highlands, however, the earth-movements have reached a greater intensity than in the southern counties of Scotland, and consequently the rocks have there in many places undergone more extreme crushing, plication, fracture and displacement. Compare, for example, the sections of the N.W. Highlands given in the Geological Survey Report (*Quart. Journ. Geol. Soc.*, 1888) with

We therefore shall proceed to examine them with regard to their direction.

This distinction of direction [or strike] with regard to strata, takes place only when they have departed from their original position; upon which occasion they must rise or fall, be elevated or depressed, in one direction or another. When they are thus disposed in any inclined plane, the line which would cut them horizontally must be at right angles with the line of their inclination; and this horizontal line is properly that of their direction.

Now if, in a certain alpine region, no regular or general direction could be found as attending the inclination of the strata, we would conclude that the elevating or disturbing cause had acted irregularly in that place; and in that case no comparison could be formed between two separate regions of this kind, with respect to the direction of that action by which their respective inclinations had been procured. But if in the one of those regions, a general line of direction

those of the Southern Uplands in the Survey Volume on "The Silurian Rocks of Scotland," 1899.]

shall be observed to take place, notwithstanding of many particular deviations, here would be a rule observed in the operations of the Earth; and it would be still more interesting to compare the rule observed in one region of this kind with that observed in another.

But it is not the distant regions of the globe, that in this respect it concerns us to compare; it is the regions sufficiently distant to be considered as distinct, and sufficiently near to be affected by the same cause. The north and south alpine regions of this country afford us precisely such an example. They are separated by a plain which is about fifty miles broad, and which has its north and south sides wonderfully straight, considering the nature of those things, and almost parallel.*

* [The straightness and parallelism between the boundary of the southern edge of the Highlands and that of the northern margin of the Southern Uplands have been determined by lines of parallel fault by which the Old Red Sandstone and Carboniferous formations have been depressed to form the broad Midland Valley. These dislocations must obviously be of much later date than the earth-movements that produced the

Upon examining those two regions, we find them having a general rule with respect to the line of direction, we also find the rule in both to be the same; and what is more, we find this line of direction to correspond nearly with the sides of the intervening plain.* Here is a most remarkable regularity in appearances which are generally or apparently involved in much confusion. But admitting this regularity, which I believe there is no reason to distrust, we are led to a conclusion extremely important to the natural history of the Earth; and this history is the more interesting to the present Theory, in that it was altogether unlooked

prevalent strike of the rocks of the Highlands and Southern Uplands, for they affect, and are therefore posterior to, the unconformable Old Red Sandstone and Carboniferous strata.]

* [The parallelism of strike between the rocks of the Highlands and those of the Southern Uplands is a prominent feature in the geological structure of Scotland, which admits of no doubt, though there is room for speculation as to its cause and as to its date, whether referable to one period of disturbance or to more than one. There can be no doubt that the later boundary faults followed the general strike of the older formations.]

for, although affording the greatest confirmation.

In order to see this, we must consider, the regularity here observed respects the operation of a great cause. We do not now concern ourselves with the variable inclinations of the strata in a mountain or a plain, nor with the particular direction in a partial view. We are surveying the effects of a moving cause which has for its subject the breadth of this island at least; and now we wish to show the importance of this regularity which has been observed.

We find the continent of Europe in no regular disposition with regard to the form of the globe or Earth in general; we find the island of Great Britain in no regular position with respect to the continent of Europe; and here we find the direction of three particular regions, two of these alpine, and an intervening plain, in no regular position with respect to this island in which these are situated; for they neither respect directly the length nor the breadth of the island, but run obliquely to them both, or between the two.

Here then is a great cause, the action of which has not been determined by anything that now appears, nor by anything perhaps that ever could appear upon the surface of the Earth. This great moving cause does not respect the original formation of the strata; it is the disordering of those strata, after they had been made, that had been the object of this operation, the effects of which we now examine. Now it is impossible to see this great cause operating upon so great a scale, and with such regular effect, without acknowledging an internal power in the globe, a power of producing land where sea had been before, and of consolidating masses which had been formed of loose and incoherent bodies.*

* [It may be inferred, though it is not quite clear from the text, that Hutton ascribed the parallelism of strike in the two regions to the operation of one cause, acting below the surface, simultaneously over the whole country. The earliest earth-movements which in pre-Cambrian time affected the Highlands seem to have acted in a N.N.E. and S.S.W. direction. In some post-Cambrian period disturbances passed across the area in a general north-west and south-east line, giving rise to the prevalent N.E. and S.W. strike. In recent years the

There remains one consideration more with regard to this regular operation; a consideration by which may be tried the justness of our reasoning. We have been representing the strata of the north country and those of the south, as having been elevated by a subterraneous power, which had acted in a certain uniform manner, by which means the line of their general direction across the island had been determined in that of the south-west and north-east, and this we find from the general stretching of the vertical or much inclined strata of those two alpine regions. But between those two mountainous regions, there is an intermediate country, in which the direction of the less inclined strata is various; and where it is not so easy to determine the general direction. For, besides the various disturbing causes which

Geological Survey has obtained evidence that bands of what appear to be Lower Silurian strata have been involved in the plication of the schists along the southern border of the Highlands. Not improbably terrestrial movements took place during a succession of geological ages in the same general direction.]

everywhere abound throughout this middle country of which we have spoken in another place;* it is always more difficult to determine, by immediate observation, the general inclination and direction of the strata in proportion as they are less inclined or more approaching to the horizontal position. But if, notwithstanding this difficulty, means shall be found for ascertaining the general direction of those strata; and if this shall be found to correspond to that which should be observed according to this theory, we would then have reason to conclude that we had formed a theory that was just.

Now we have but to examine the coal and lime strata, which have been so well explored and so carefully pursued; if these strata in general follow the line of direction proper to the alpine regions, we shall have

* [The reference here may be to some account of the Midland Plain of Scotland in the portion of the MS. of vol. iii, that has not been recovered. The region, however, is alluded to in various chapters of the two previous volumes. See for instance vol. i, pp. 82, 96, 115, 153, 158, 428, 454, 467, 480, 598, 601, 603, 611, 616; vol. ii, pp. 65, 417.]



every confirmation to the theory which the nature of things will admit of. But this is certainly the case; the coal strata stretch along the north side of the south alpine region, from Dunglass in East Lothian* to Girvan in the shire of Ayr, and on the north side of this plain country, the coal runs parallel with the north alpine region, from St. Andrews to Stirling, and from that to the island of Arran and peninsula of Kintyre, almost in a direct line.†

Let us now sum up the doctrine. We have found certain marks, in the composition of the strata, by which those of the south alpine region may be distinguished from those of the north; at the same time we have every reason to conclude, that those

* [See vol. i, p. 454.]

† [Although it is true that the younger formations which underlie the Midland Valley have a general distribution parallel to that of the older rocks of the Highlands and Southern Uplands, there is on the whole no general parallelism in the strike of their strata. The rocks of the Midland Valley have obviously had their strike determined by a later series of movements than those which were mainly concerned in the production of the parallel strike of the regions to the north and south.]

different strata are the same species of bodies, and had a similar origin in the bottom of the sea, as well as a similar process for erecting them into their present state. Also, between those two regions of distinguished strata, we have found a great space containing strata, which with respect to materials are considerably different, although as to the general manner of their formation they are similar. But what seems most remarkable, is that general regularity in the direction of all those various strata, a general regularity which may be perceived amidst the confusion of infinite particular perturbations, and which would indicate the action of one great cause, or a certain generality in that operation by which the bottom of the sea had been erected into the place of land.

It will now be allowed us to observe that the notion of primitive, secondary and tertiary mountains, which has of late so much prevailed among philosophers or naturalists, is not well founded.* At the

* [In the famous memoir by Pallas, "Observations sur la formation des montagnes" (*Acta Acad. Scien.*

same time, it must be confessed, that there are certain appearances which might naturally lead them into that error. At the bottom of the schistus mountains, where those alpine regions terminate in the plain or lower country, it is not unusual to find very compound masses, in which there is much of the *débris* of all the strata in the neighbourhood.

It must be evident that such masses are secondary, in relation to those strata, the fragments of which are found within those masses. It must be also evident, that strata formed in the bottom of the sea, and indurated or consolidated by the force of subterraneous heat, could not be broken and erected into the state of almost vertical strata, without having produced abundance of fragments and detritus; and that this should be naturally collected and formed into a mass in this very place, is most reasonable to suppose, even when we had not the testi-

Imper. Petropol., vol. for 1777,' pp. 21–64) primitive, secondary and tertiary mountains are spoken of as if there could be no doubt of their existence. See also De Saussure, *Voyages dans les Alpes*, § 131 (1779).]

mony of observation, which frequently makes it evident.*

But from this view of things, there is no

* [There is a little of the characteristic Huttonian obscurity of style in this and the four previous paragraphs. Hutton argues that the general coincidence of strike not only between the rocks of the Highlands and those of the Southern Uplands, but between both and those of the Midland Valley furnishes ground for the belief that the elevation of all these originally marine formations into land proves the operation of one great subterranean agency. It might be supposed from the text that he regarded the elevation of the three regions as one simultaneous process. But he demonstrated that the "alpine schistus" of Berwickshire had undergone great disturbance before the deposition of the red sandstones upon it. He does not, however, here enunciate the view that the agency which he invoked had operated over the same region and in the same direction, during successive geological periods in the history of the same continent. He hardly seems to have realized that the unconformability which in 1788 he detected on the Berwickshire coast, while it proved the disturbance of the "schistus" to be older than the red sandstone, showed also that all the thick mass of strata conformably overlying the red sandstone could not have been affected by the far older movements that threw the "schistus" into a vertical position, but may have spread over all the Southern Uplands and

reason to suppose that there is any other system in nature besides that which has been now exposed; a system in which the old continents are wearing away, and new continents forming in the bottom of the sea; and a system in which the subterranean power of fire, or heat, co-operates with the action of water upon the surface of the

buried them. He might object to the terms primitive and secondary mountains; but he himself furnished the demonstration that the hills of the east of Scotland must be of at least two vastly different ages.

The evidence for wide intervals between the formation of at least three great groups of rock was clearly indicated by Pallas in the essay cited in the previous note. Reasoning chiefly from the structure of the Russian empire, this observer came to the conclusion that the primitive mountains, consisting of granite, schists and other rocks in highly inclined or vertical positions, took their origin before the appearance of organized beings on the surface of the earth; that these ancient rocks are encircled by less inclined and lofty strata of limestone (secondary mountains) which with their abundant petrifactions contain the earliest legible records of the history of our planet; and that at still lower levels came marly, sandy and gravelly deposits enclosing the chronicles of the latest terrestrial revolutions (tertiary mountains).]

Earth, for the restoration of that order of things which is necessarily lost in the maintaining of a living world—a world beautifully calculated for the growth of plants and nourishment of animals.

CHAPTER VI.

A comparison of M. de Saussure's observations in the Alps, with those made upon the granite mountains of Scotland.

I HAVE been particularly anxious about this subject of granite ; it is not only with a view to refute the notion of primitive mountains, a part of the Earth which should be inexplicable to man, who judges, according to the laws of nature, of that which had been transacted in a former period ; it is also in the hopes of acquiring more light into the natural history of this Earth, by understanding the origin of those granite masses which had appeared to naturalists as the first of things.

I had longed to see the continuation of M. de Saussure's *Voyages dans les Alpes*,*

* [The first volume of De Saussure's great work was published in the year 1779 ; the second in 1786. It was the latter which Hutton had been so impatiently expecting. He received it after the foregoing chapter had been written, and he made use of it in writing the

but it was not till I had written an account of our second expedition to the granite mountains of this country that I received it. The reader will guess the impatience I felt to see what interesting observations this able naturalist had made, with regard to the junction of the granite and schistus in the Alps. I have every reason to be satisfied with M. de Saussure; but the success of his labours did not come up to my sanguine expectation or my wishes. It is but in few places that this junction of those different bodies is to be perceived; at least, our author, though carefully looking for this occurrence, met with it rarely. In having been so fortunate myself, I perhaps expected too much from those alpine scenes, where the difficulty of making

first two volumes of his *Theory* which appeared in 1795. The third and fourth volumes of the *Voyages* were published in 1796, and were received by Hutton a few months before his death, during the progress of the illness which carried him off in the spring of 1797. Playfair tells us that these volumes particularly pleased the author of the *Theory of the Earth*, and that they "became the last study of one eminent geologist, as they were the last work of another." *Works*, vol. iv, p. 102.]

the proper observations increases with the grandeur of the object. M. de Saussure has at least discovered one remarkable and interesting scene of this kind; I had expected many.

The purpose of this chapter is to endeavour to show that M. de Saussure has described something of the same kind with that which I have now several times observed in this country. It is an observation which our author has made in the Alps, and which he has also with his usual accuracy faithfully delivered. It is true indeed, that our author's view of this natural phenomenon is in some measure diametrically opposite to mine; but it is just so much the more interesting to the present Theory, if it is with such a theory alone that this natural appearance will coincide. To a common observer, the prejudice of an invented or received theory perverts the nature of a phenomenon, and often infects the description of a fact, so as to make it to be misunderstood. It is not so with M. de Saussure; with him the accuracy of the natural historian always triumphs over the prejudices of the philosopher; and though with other

views at the time, he might perhaps have observed some particulars which then escaped the diligence of his research, his theory has not suggested anything to his description. I think myself fortunate in having written the histories of my mineral observations, before I had read the second volume in which those of M. de Saussure are recorded; for it will thus be seen what natural correspondency there is to be observed between these mineral appearances of Scotland, in the history of which no influence of description had intervened,* and those of the Alps, in the observa-

* [It is curious to observe that while the author here claims that no influence of a theoretical kind affected his account of the granite junctions, he confesses in the very next sentence that he "laid aside every other consideration," in order to devote his undivided attention to "the manifestation of fluidity or fusion in the granite." There can be no doubt that he had formed his theory of granite before he ever obtained on the ground any evidence of the intrusive nature of that rock. In fact all his journeys in Scotland in quest of granite junctions, beginning with the visit to Glen Tilt where, for the first time, he saw intrusive veins and dykes proceeding from a mass of granite, were made for the purpose of proving the truth of a theory which he had already propounded and published. It must be remembered, however, that

tion of which such different views of cosmogony had occupied the mind of the naturalist.

In making this comparison of those descriptions, it will be proper to observe that I had one principal object in my view; I therefore laid aside every other consideration which might interfere with the subject of examination. This was the junction of the two different rocks, and the manifestation of fluidity or fusion in the granite mass, from this body breaking and invading the alpine strata. M. de Saussure had in his description no such object in his view, but, on the contrary, if there is any particular point to be ascertained, it is that of the stratification of granite in general, notwithstanding those appearances of masses in which no distinct mark of stratification appears. This is professedly M. de Saussure's object upon this occasion; but this was an object which I held only in a

he had lived long among abundant proofs of the igneous origin of the "whinstones" of central Scotland, and that the conclusions which he had formed from observation and reflection regarding these rocks might seem to him to be perfectly applicable also to granite. See pp. 24–25.]

very secondary view; because, could it be once properly demonstrated that masses of fluid granite had been forced to flow among genuine strata, all appearances will be explained, and it will become a secondary consideration only, to enquire how far genuine granite may be found also truly stratified in its original composition, as well as apparently from its injection and interposition among bodies which had been stratified.

It is necessary to attend to this distinction of different views in M. de Saussure's description and mine; more particularly as I do not propose to examine that secondary question with regard to the original formation of those masses which are considered as genuine granite; it being perfectly indifferent to the Theory which is now endeavoured to be established, whether or not upon some or many occasions the great masses of granite shall be found to have been truly stratified originally in water like those of limestone.*

* [That granite was a chemical precipitate from a primæval universal ocean was one of the fundamental doctrines of Werner, and was the generally accepted view when Hutton wrote. Even the illustrious De

It was an important object with M. de Saussure, as a true philosopher, to show the impropriety or error of a doctrine which had prevailed; this was, that there were primitive mountains of granite, masses of solid rock which had not been formed by any operations natural to this globe. I think that M. de Saussure has succeeded so far in his careful investigation of nature; but in so far he has also confirmed the present theory.

We are therefore to lay aside at present every consideration with regard to the stratification of granite, a consideration with which we are not immediately concerned: and we are to endeavour to perceive in the observations of M. de Saussure a generalization of phenomena, in finding a similarity of appearances between mineral objects in the centre of the Alps, and in the alpine regions of this country; appearances from whence the most positive conclusions may be formed with regard to the last operations of nature in the mineral regions, where masses of

Saussure, who was so familiar with the granites of the Alps, remained up to the last a believer in their aqueous origin.]

granite and the alpine strata are so much confounded.

It is an undisputable fact that there are strata composed of the same materials with those of the most massy granite; nevertheless the constitutions of those two stones are distinctly different. In the one, the constituent parts of the stone are evidently stratified; in the other again, there is either no regularity whatever to be perceived, or if there be regularity, it is not that of stratification.* There may indeed be intermediate species, with regard to which a naturalist may be doubtful whether to place them among the one or other of those two different species; but still the constitution of those two compositions is perfectly marked, the one carrying in it the most convincing evidence of stratification, the other no such mark. Therefore, it is only one of these two species of stone which preserves undoubted evidence of its original constitution, as having been collected by subsidence in water, or composed of loose materials broken and detached from former

* See an example of this in Part I, Chap. 2 [vol. i, pp. 264–268].

rocks, and as having been afterwards consolidated in the general operations of the globe for making land of that which had been at the bottom of the sea.

But though we cannot immediately trace the origin of that species of granite which is in mass from the collection of its materials, as we do the other which is stratified, we have the most decisive proof of the last operation of fire by which this rock had been in a fluid state; because everywhere in this stone there are marks to be found of a fluid state. But particularly in those places where the granite mountains are contiguous with the alpine schistus or stratified bodies of the Earth, there is absolute demonstration that the granite mass had been made to flow in the manner of subterraneous lava; for, the strata are so broken and involved in that solid rock, and veins of the solid rock so interjected among the broken and involved strata, that it is not possible to conceive any other way in which the visible effects may be explained.

It is not, however, everywhere that such convincing proofs of the mineral operations

are exhibited; perhaps they are more rare than what from my experience I should have reason to suppose. I have been so fortunate as to meet with these in three different parts of the country, one in Athol, the other two in Galloway; but it sometimes required extraordinary pains, and a minute acquaintance with the nature of the subject, to make those striking or most convincing objects to be observed. I hope I have given such directions where they are to be seen, and how to be observed, that any naturalist in following my steps, will find little or no difficulty of gratifying himself with such a view of those minerals as leaves no room to doubt, and this with regard to a subject which is of great importance to the natural history of this globe.

Before entering upon the history in transcribing our author, something may be premised, with the view of stating the case which is to be under consideration.

M. de Saussure had found that the centre of the Alps, considered as placed in Mont Blanc, was composed of those huge masses of granite which stand up in form of stu-

pendous pyramids. This region of granite runs in the direction of north-east and south-west, along with the valleys that are formed among those ridges of mountains. He had also found reason to suspect or almost conclude with certainty, that originally the intervals between those ridges of mountains, and among the masses of granite, had contained stratified bodies of inferior hardness solidity, or durability to that of the perfect granite, the relics of which chiefly now are seen.* The places of those decayed and destroyed masses of inferior durability form the valleys which are filled either with fertile soil, or glaciers, according to their situation with respect to height and position in relation to the snowy tops of those mountains where perpetual winter reigns.

The Valley of Chamouni, in which runs the River Arve, is a low valley immediately to the north-west side of those icy valleys and those ridges of granite mountains. The stratified bodies or alpine strata which compose the north-east of the valley of Chamouni, are pretty horizontal there, and

* See *Voyages dans les Alpes*, tome ii, page 30.

are heading or rising a little to the valley; but as we recede from the valley of Chamouni, in going towards the granite mountains, those horizontal strata become more and more erected towards the vertical position; and it was in pursuing this track that M. de Saussure went to examine those masses of granite the centre or summit of which he could not reach, however curious he was to know the composition of those central masses.

Here we have M. de Saussure set out to form a similar enquiry in the Alps, to that which I have been making in this country. M. de Saussure would seem to have set out with the idea of primitive mountains, an idea inconsistent with the present Theory; but like a true philosopher, his theoretical ideas only serve to direct his research, and never to pervert his observation. It is therefore extremely interesting to know what this expert naturalist shall find with regard to the connection of the granite with the alpine strata, a connection which in my observations has thrown so much light upon the subject of granite and primitive mountains,

and which has added a confirmation to the Theory, beyond what the most sanguine expectation could conceive.

The first connection of the granite with the alpine strata, which M. de Saussure found, was at the foot of the Aiguille de Blaitiere. He had mounted up as far as he could go upon the side of this granite pyramid; it was impossible to reach the top; and now we shall follow him in the observations which he is to make.*

"J'avois de ce point-là une vue très-"étendue ; mais ce qui me touchoit le plus, "le cœur de mon aiguille, ne me donna pas "beaucoup de satisfaction. Le granit dont "elle étoit composée, parfaitement sembla-"ble, quant à sa composition, à celui que j'ai "décrit plus haut (§ 659) ne laissoit apper-"cevoir aucune régularité dans sa structure : "les fentes qui le divisoient étoient dirigées "indifféremment en tout sens ; ici, elles "sembloient parallèles ; mais plus loin, on "les voyoit converger et diviser le roc en "grandes masses cunéiformes ; ailleurs, elles

* [*Voyages dans les Alpes*, tome ii, p. 67 *et seq.* The quotation begins in § 660.]

" étoient courbes et coupoient les rochers en
" parties, concaves d'un côté et convexes de
" l'autre. Le seul fait général que l'on pût
" observer, c'est que ces crevasses, quelle
" que fût leur forme, étoient toujours nettes
" et tranchées, sans dentelures, sans bavures;
" en sorte que les faces des blocs qui en
" résultoient étoient toujours, sinon polies,
" au moins lisses et unies.

" Je descendis le glacier de côté opposé à
" celui par lequel je l'avois monté, et par une
" pente si roide, que si la neige eût été dure,
" il eût été impossible de se retenir; un
" accident fit tomber le chapeau de Pierre
" Balme, mon fidele guide, et il roula
" jusqu'au bas du glacier sur le tranchant de
" son bord; nous le crûmes perdu, parce
" qu'il devoit naturellement tomber dans une
" grande crevasse que étoit au-dessou des
" nous, au milieu du glacier, mais il en fit
" le tour, et il échappa au danger avec une
" légéreté et une apparence d'intention et
" d'addresse tout-à-fait singuliere.

" § 661. Dès que je fus sorti du glacier
" et des neiges qui descendoient encore
" fort au-dessous de lui, je cherchai une

" place où je pusse prendre quelque repos
" et un peu de nourriture. Je trouvai un
" siege de gazon commode sur une hauteur
" qui dominoit une vaste étendue couverte
" de ces débris, dont j'avois tant traversé
" dans cette journée. Mes yeux ne dé-
" couvroient et même ne cherchoient dans
" ces débris rien d'intéressant. Cependant,
" lorsque le repos et la diminution du froid
" insupportable, dont mes jambes avoient
" été saisies pendant un séjour de plus de
" deux heures dans la neige, eurent rendu
" un peu d'activité à mes sens et à mon
" attention, je crus appercevoir quelque
" chose de régulier au milieu de ce chaos ;
" il me sembla voir des bandes de rocher
" bien suivies, qui élevoient leurs têtes
" au-dessus de la surface de ces débris.
" L'espérance d'une belle observation acheva
" de me remettre ; je me hâtai d'y descendre.
" Mon attente ne fut pas trompée ; j'ob-
" servai là un fait rare et intéressant, des
" bancs de granit encaissés dans des couches
" de roches feuilletées. Le plus élevé
" étoit un banc parfaitement régulier d'un
" granit en masse bien caractérisé. Son

" épaisseur partout uniforme étoit de 12 à
" 15 pieds. Les couches que le bordoient ou
" l'encaissoient étoient d'un granit feuilleté ;
" l'épaisseur de ces couches varioit depuis
" un pied jusques à deux ou trois pouces ;
" elles étoient toutes parfaitement régulieres,
" dirigées comme la vallée de Chamouni, du
" nord-est au sud-ouest, et dans une situation
" exactment verticale. Un peu plus bas, je
" trouvai un second banc de granit, sem-
" blable au premier, quoiqu'un peu moins
" biens caractérisé, encaissé dans des
" couches qui n'étoient plus un granit
" veiné, mais un roc blanc, quartzeux,
" feuilleté ; la direction et la situation tant
" du granit que des roches feuilletées
" étoient parfaitement conformes à celles des
" précédentes. Au-dessous de ce second
" banc, j'en trouvai un troisième, et d'autres
" successivement, jusques aux couches ver-
" ticales que j'avois traversées le matin
" au-dessus de Blaitiere (§ 658) mais à
" mesure que ces bancs s'éloignoient des
" hautes aiguilles, ils s'éloignoient aussi de
" la nature du granit, et se rapprochoient
" de celle des roches ordinaires, mêlangées

" de quartz et de mica, avec lesquelles ils
" venoient enfin se confondre.

" § 662. Ces dégradations et cet encaisse-
" ment me paroissent démontrer avec la
" derniere évidence, que le granit a été
" formé précisément de la même maniere
" que les roches feuilletées. Car comment
" pourroit-on supposer que ces bancs ou
" ces couches épaisses de granit, renfermées
" entre des couches d'une autre pierre,
" conservant partout la même épaisseur, la
" même situation, suivant la même direction,
" pussent avoir une origine différente ? Et
" si l'on joint à cette considération celle de
" la nature même de la pierre, qu'on
" réfléchisse que le granit veiné qui encaisse
" le premier de ces bancs, ne differe du
" granit en masse qu'il renferme, que par
" la disposition de feuillets de mica, lesquels
" sont confusément dispersés dans l'un, et
" arrangés sur des lignes parallèles dans
" l'autre ; qu'à cela près tout est pareil
" entr'eux : j'avoue que je ne saurois
" comprendre que l'on puisse prétendre à
" en faire des êtres de nature absolument
" différente. En effet, comme je l'ai déja

" observé, on voit très-fréquemment dans
" des montagnes d'un autre ordre, des bancs
" de pierre en masse, calcaire, par example,
" dans lesquels on ne peut pas appercevoir
" la moindre apparence de feuillets, alterner
" avec des couches feuilletées de même
" genre, ou d'un genre différent ; et personne
" ne doute que, malgré la différence des
" tissus, ces bancs et ces couches n'aient eu
" la même origine.

" D'ailleurs, cette différence de tissu s'ex-
" plique d'une maniere très-naturelle par les
" principes les plus généralement adoptés
" sur la formation des montagnes. En
" effet, qui pourroit douter que les liquides
" quelconques, dans lesquels ou avec les-
" quels ont été formées les montagnes,
" n'aient été sujets à des variations ; qu'ils
" n'aient charié, tantôt certaines matieres,
" tantôt d'autres ? Or ces alternatives de
" mouvement et de repos suffisent seules
" pour expliquer les alternatives de roches
" en masse et de roches feuilletées.

" Je suis donc pursuadé que les grandes
" masses de granit dans lesquelles on ne
" voit aucun indice de feuillets ou de sub-

" divisions régulieres, ne sont autre chose
" que des couches très épaisses, formées
" pendant les intervalles de stagnation du
" fluide, dans lequel les mountagnes ont
" été engendrées. Il paroit même que les
" masses de ces pyramides, dont nous ne
" pouvons pas sonder l'épaisseur, sont
" entrecoupées par des bancs de roches
" feuilletées. Car j'ai trouvé de nombreux
" fragmens, et de granits veinés et de
" roches feuilletées, au pied des aiguilles;
" à des hauteurs où je ne voyois plus
" au-dessus de moi que des granits en
" masse; et ces fragmens ne pouvoient
" venir que du milieu de ces mêmes
" granits."

Here M. de Saussure inclines to make the central masses of the Alps to be of the same formation with those regular bodies of granite which he has found placed among the alpine strata. I am perfectly agreed with our author, only with this difference, that I suppose those regularly formed granites to be of the same nature with the central masses; this will require some explanation.

M. de Saussure supposes that he understands the formation of those granites which he found inclosed between the alpine strata; consequently, it is by this means that he would explain the central masses, the formation of which he does not comprehend. I, again, suppose that I understand the formation of those irregular masses of granite; and it is by means of this knowledge that I am inclined to explain those regularly formed or apparently stratified granites, which I do not suppose to have been stratified originally along with the *granit feuilleté* with which they are inclosed. In the light in which M. de Saussure considered the subject, he had no distrust of those inclosed granites being strata; consequently, it is possible that he may have neglected making some observation by which this question might have been absolutely decided. But it is probable that there was not enough of the solid strata seen to lead a person who had not this particular view in his head, to make a conclusion so very different from that which the first appearance must suggest.

In the present state of things, I am disposed to believe, that those apparently stratified granites were truly great veins interjected between the alpine strata; and therefore that they differ totally or, at least, in this respect, from the stratified granite with which they are inclosed, while they perfectly agree with the granite mass of the pyramid or mountain, in having been produced at the same time or in a similar manner.*

* [Although since the time of De Saussure the protogine or alpine granite with the associated crystalline schists have been often visited and described, they still present problems that await solution. The great pioneer of Swiss geology believed that the schists and granite were both formed in the same way by deposition from water. He observed that the granitic character becomes less marked as the rocks are traced away from the Aiguilles, that is, in proportion as they recede from the mass of granite. Hutton looked on the successive sheets of granite interposed among the schists as so many intrusive apophyses from the main body of that rock in the central part of the mountain chain. That the granite was erupted as an igneous magma into the schists has long been admitted, so that Hutton's main contention has been confirmed; but the history of the foliated rocks of the central chain of the Alps, their

Let us see what our indefatigable author is to meet with next.

" § 663. Le lendemain, 30 Août, je pro-
" cédai à l'examen de la quatrieme pyramide,
" la plus voisine de l'aiguille du midi, et qui
" se nomme *l'aiguille du Plan.* Pour arriver
" à son pied, je tirai plus à l'ouest que je
" n'avois fait la veille, et je vins en trois
" quarts d'heure passer devant le chalet de *la*
" *Tapie*, situé dans un fond extrêmement
" sauvage, au pied du glacier *des Nantillons*,
" et entouré de toutes parts de débris de
" rocher, chariés par ce glacier.

" À un bon quart de lieue au-dessus de ce
" chalet, je passai auprès d'un petit lac assez
" profond, nommé *Lac du Plan de l'aiguille.*
" Ses eaux, quoique parfaitement pures et
" limpides, paroissent d'un verd d'émeraude :
" leur température à l'ombre, près de la
" surface, est de 4 degrés et demi, tandis
" que celle de l'air est de 7⅓ degrés. Les
" rocs qui le bordent à l'ouest sont composés
" de feuillets minces, mêlangés de quartz et

geological age, their origin and the manner in which they have acquired their present structure are still moot points among geologists.]

" de mica, courant du nord-est au sud-ouest,
" et inclinés en appui contre le nord-ouest.
" Tous ceux que j'ai traversés aujourd'hui
" ont cette même situation générale (§ 656).

" Un peu au-dessus du lac, dans ce même
" roc feuilleté, on trouve un banc de talc
" jaunâtre, très-doux au toucher, mais mêlé
" par places de rognons de quartz.

" § 664. Je laissai ce lac à ma gauche, et
" en continuant de m'élever, je rencontrai des
" bancs qui s'approchoient par gradations de
" la nature du granit, et enfin, un banc de
" vrai granit en masse. Ces bancs sont
" vraisemblablement une prolongation de
" ceux que j'avois vus la veille (§ 661); du
" moins sont-ils dans la même direction, et
" encaissés comme quelques uns d'entr'eux
" entre des feuillets de roche quartzeuse
" micacée. Ce banc n'a cependant que deux
" à trois pieds d'épaisseur, et même il ne
" conserve pas la même nature dans toute
" son étendue; car en courant au sud-ouest,
" il se change en roche feuilletée. C'est une
" propriété remarquable des roches formées
" par crystallisation, et qui est une consé-
" quence bien naturelle de la nature de cette

" opération, que de n'avoir point dans leurs
" couches la même constance que les roches
" qui doivent leur origine à des dépôts.

" Tout près de-là, je trouvai de jolis
" morceaux de fer spéculaire adhérens à des
" fragmens de quartz.

" Plus haut, toujours dans le débris, je
" rencontrai un superbe banc de granit en
" masse, large de 40 à 50 pieds, encaissé du
" côté supérieur par des couches d'un granit
" en masse précisément de la même nature,
" et de six pouces à un pied d'épaisseur.
" Ces bancs sont verticaux, et dirigés du
" nord-est au sud-ouest, comme tous ceux de
" ces montagnes. Ils n'ont pas le même
" genre d'irrégularité que les précédens ; ils
" conservent bien dans toute leur étendue la
" nature du granit, mair leurs divisions ne
" se prolongent pas constamment dans toute
" la longeur de la pierre ; ici, elles s'ob-
" literent, deux couches distinctes se soudant
" entr'elles pour n'en former qu'une seule ;
" là, il en naît de nouvelles par la sub-
" division de l'une d'entr'elles ; et c'est
" encore un effet naturel de la crystallisation ;
" mais ce qui seul est essentiel à la question

" de l'existence des couches, c'est que ces " divisions ont toujours une seule et même " direction.

" De-là aux aiguilles, tout est granit, mais " tellement couvert de débris énormes, que " l'on n'apperçoit que très-rarement le fond du " sol. Je trouve cependant au pied même " de l'aiguille, de beaux feuillets verticaux de " granit en masse de différentes épaisseurs, " depuis deux pouces jusqu'à quatre pieds, et " dirigés du nord-est au sud-ouest, comme " toutes les couches de ces montagnes."

Here I do not see any evidence for the stratification of those masses of granite. M. de Saussure, in whose judgment we may confide, is clearly of opinion that they are not stratified in the usual manner, as having been formed by subsidence in water, but that they had been formed in a different manner. Therefore I must be still inclined to suppose, that it is the mountain or massy granite which is here injected among the alpine strata, and that this granite mass had only been stratified in flowing between those regular bodies.*

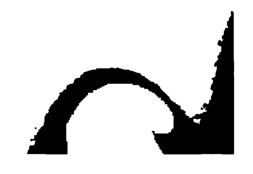
* It would seem that this is not an unusual appear-

Now had M. de Saussure seen nothing farther than those examples, I should have been extremely disappointed; and yet this

ance near the junction of the granite and alpine strata. A very fine example of this is found near Riesen Geburge in the mountains which divide Bohemia and Silesia. It is in one of the highest mountains named Schnee Kappe. In this mountain is found the junction of the granite and alpine strata. These two different masses compose extensive mountains of alpine strata on the one hand, and pure granite on the other; but where they meet, those two masses are alternated, the granite appearing in strata between those of the gneiss and other alpine strata; but the great mass of granite is not stratified. This particularity is also observable, that next to the great mass of alpine strata, the strata of the granite are thin, while those with which they are alternated are thick; whereas next to the mass of granite, it is the reverse, the granite being thick and the alpine strata thin. This information I have from Count Reden.

[Besides occurring in beds or sheets of massive or amorphous structure, intercalated among the surrounding strata, granite sometimes presents a distinctly laminated or foliated arrangement of its component minerals along the line of junction and for some distance away from it, becoming a kind of gneiss the foliation of which runs parallel with the general line of boundary. It is worthy of remark that this contact-phenomenon is particularly well exhibited along some parts of the edge

I 2



might very well have been; for, having with great trouble and fatigue visited three or four of these pyramids, few naturalists would have thought of staying another night at the châlet in order to undergo the labours of another day. It is, however, upon the fruits of this day's labour that I am to ground my opinion with regard to the granite of the Alps, in generalizing the knowledge which I have already acquired of the subject in examining the granite mountains of this country. I hope the history of that day's work will be as acceptable to the reader as it was to me.

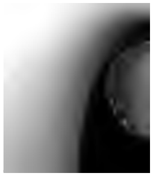
Having after much pains arrived at the foot of the Aiguille du Midi, M. de Saussure thus continues his description.

"§ 674. Je suis bien dédommagé de ma "peine, ce rocher est un des plus extra-

of the great Criffel and Kirkcudbright granite mass described in the preceding chapter. It is possible that in his visit to that granitic area Hutton may have seen this gneissose border, but if he had connected it with any stratification from flowing between other rocks he might have been expected to make fuller reference to it in support of his theory than the conjecture expressed in the text.]

" ordinaires que j'aie jamais vus : un mêlange
" bisarre de vrai granit en masse avec une
" roche grise, pesante, qui tient de la roche
" de corne, qui n'a aucune ressemblance avec
" le granit, et qui prend au-dehors une
" couleur de rouille. Ici, c'est un banc de
" granit encaissé entre des couches de cette
" roche ; là, le même banc est par places de
" granit, par places de cette roche ; plus loin,
" ce sont des filons transversaux ; ailleurs,
" des rognons de granit renfermés dans cette
" même roche. D'ailleurs, tout le rocher est
" divisé en couches bien prononcées, verti-
" cales, dirigées du nord-est au sud-ouest.
" La crystallisation seule peut expliquer des
" mêlanges aussi singuliers. Dans un fluide
" qui tient en dissolution différentes matières
" qui se crystallisent, le moindre accident
" détermine les élémens de l'une de ces
" matieres à se réunir en très-grande abon-
" dance dans certaines parties du vase : un
" autre accident change cette détermination,
" et oblige les élémens du même genre à
" aller se reunir dans une autre place.

" Mais l'aiguille entiere n'est pas composée
" de ce singulier mêlange : tout le cœur et le





" haut du l'aiguille sont d'un beau granit pur,
" semblable à celui des autres aiguilles ; il n'y
" a que cette partie de son pied, et celle du
" sud-ouest que je vois très-distinctement, qui
" soient composées de ces rochers mêlangés."

The interesting fact, with regard to this valuable observation, consists in this, that there is a certain mixture or confusion of granite and the alpine strata. It would have been still more interesting, indeed had M. de Saussure distinguished in this mixture which of the two different rocks was the containing and which the contained body; that is to say, which of those two bodies had broken and invaded the other.

In the places where I have examined the junction of the granite and the schistus, there is nothing more evident than this fact, that the one of those two bodies had been broken and invaded by the other; and I have brought the most satisfactory cabinet specimens of this appearance, although anything that can be brought gives a faint idea of what is there found in nature.

There is an expression, indeed, of M. de Saussure which does not correspond with

anything I have seen; it is this, "des rognons de granit renfermés dans cette même rôche." If our author means that there were insulated pieces of granite contained in the rock or enclosed within it, and that this rock was of the alpine strata, it must be an example different from any that I have seen; for, in those which I have seen, it is pieces of the rock that may be found floating or insulated in the granite, and not any of the granite in the rock. It is, indeed, evident that this was not the view which M. de Saussure had taken of the subject; for, seeing a great confusion of those two objects, our author thinks that those two bodies had been formed *pari passu*, or at the same time; by crystallization from a state of aqueous solution. But as I hope to have shown that this separation from a solution is not the way in which the mineral bodies of our globe have either been formed originally, or consolidated after they were formed; and as with this view of the subject, which M. de Saussure had taken, he could never have thought of describing an idea which had not suggested itself, I think I may be allowed to suppose

that the same fact might here be perceived, which occurs in many different places of this country, namely, that it is the granite which has evidently broken and invaded the strata thus displaced by the granite, and not contrarily the granite by the alpine strata.*

M. de Saussure describes what he observed in examining the other side of the central granite mass, that side which respects Italy, in the entry to the Vallée de Ferret. As the granite is here found contiguous with the alpine schisti, every observation that can be made is interesting, and I would wish to give every means of judging with regard to a subject which does not lie in the way of many naturalists to observe.

"§ 860. Ce col, élevé de 1195 toises

* [Among the phenomena attending the "granitisation" of rocks, or their absorption and transfusion by a granitic magma, laminæ, veins and nodular lumps of granitic material seem to be separately enclosed within the metamorphosed mass. De Saussure's observation was therefore no doubt accurate, but Hutton had not seen much of the phenomenon of extreme granitisation and did not realize how exceedingly complex the junctions of granite with the surrounding rocks sometimes are.]

" au-dessus de la mer, d'après mon observa-
" tion du barometre, est en face du col de la
" Seigne et a l'extrêmité opposée de la même
" vallée. Cette vallée continue de séparer
" ici la chaîne primitive centrale, des pre-
" mieres chaînes secondaires. Ce n'est pas
" qu'il n'y ait quelques mêlanges ; que l'on ne
" trouve, par exemple, des ardoises et des
" calcaires au pied de ces primitives et même
" à l'entrée de quelques-unes de leurs gorges,
" comme l'on retrouve ici d'autres primitives
" derriere la premiere ligne des secondaires ;
" mais en général les cimes de la droite sont
" granitiques, et celles de la gauche calcaires.

" La direction générale de la vallée, en
" tirant une ligne droite du Col Ferret au
" Col de la Seigne, est du nord-est au sud-
" ouest ; mais elle se courbe dans le milieu
" où elle devient un peu convexe du côté du
" sud-est.

" Toutes les secondaires qui bordent la
" gauche ou le côté sud-est de cette vallée,
" ont leurs couches inclinées en appui contre
" la chaîne primitive. On le voit distincte-
" ment du haut du col, et mieux encore d'un
" peu plus bas.



" Quant à la chaîne primitive, elle ne
" présente pas ici une organization bien
" distincte ; on ne voit pas le Mont-Blanc, il
" est caché par des cimes moins élevées mais
" plus proches. Ce qui attire toute l'atten-
" tion du spectateur, ce sont deux grands
" glaciers qui descendent de la chaîne primi-
" tive tout auprès du Col Ferret. Le plus
" voisin de ce col ce nomme le *Glacier du*
" *Mont-Dolent* ; son plateau le plus élevé,
" est un grand cirque entouré de hauts
" feuillets de granit de forme pyramidale ; le
" glacier descend de là par une gorge dans
" laquelle il est resserré ; mais dès qu'il l'a
" dépassée il s'élargit de nouveau et s'ouvre
" en éventail. Il a donc en tout la forme
" d'une gerbe, serrée dans le milieu et dilatée
" à ses d'eux extrêmités. L'autre est le
" glacier *du Triolet*, moins grand et couvert
" des décombres d'une haute montagne de
" granit. Il se fit, il y a environ 60 ans, du
" haut de cette montagne, un éboulement
" considérable, qui ensevelit dans une nuit
" les chalets qui étoient au pied de ce glacier,
" avec les troupeaux et les bergers. Dès
" lors ces éboulemens ont toujours continué.

" Ces deux glaciers sont séparés par une
" montagne qui se nomme le *Mont-Ru* ; elle
" est de granit, et comme elle me parut
" accessible vers son pied, je résolus d'aller
" la sonder dès que je serois descendu au
" fond de la vallée.

" § 861. Le col même de Ferret est
" composé de grès feuilletés et d'ardoises
" tendres, dont les feuillets ne s'écartent de
" la situation verticale que pour s'appuyer
" contre les montagnes primitives. Leur
" direction est au sud-sud-ouest, comme
" cette partie de la vallée. Ces ardoises
" sont entremêlées de quartz, en couches,
" tantôt épaisses, tantôt minces ; ici entier,
" là carié sous mille formes différentes.

" § 862. La descente est très-rapide,
" dangereuse même pour les mulets quand
" il a plû, parce que les ardoises décomposées
" sur lesquelles on passe, forment un ter-
" rein extrêmement gras et glissant. Cette
" pente est, comme le haut du col, com-
" posée d'ardoises et de grès feuilletés ;
" mais on y rencontre de plus, des bancs de
" pierre calcaire de couleur d'ardoise, et
" cette derniere pierre forme seule la partie

" la plus basse de la montagne, du côté de
" la chaîne centrale. Les couches de toutes
" ces pierres ont constamment la même
" situation que celles de haut du col."

" § 866. Des chalets je descendis au fond
" de la vallée, et là, pour aller observer le
" pied du Mont-Ru, qui sépare les deux
" glaciers (§ 813), je m'écartai de la route
" battue, et je guéai sur mon mulet, non sans
" quelque difficulté, le torrent qui sort du
" glacier du Mont-Dolent. Arrivé au pied
" de ces rocs, je les trouvai composés d'un
" granit dont je ne pus pas démêler la
" structure : en l'observant de si près, je ne
" voyois que de petites fentes dont les
" directions n'étoient point parallèles entr'
" elles. Mais je trouvai la face de la
" montagne qui regarde la vallée, revêtue en
" divers endroits d'une pierre dure, jaunâtre
" feuilletée, dont des plans couroient au
" sud-sud-ouest comme cette partie de la
" vallée. Ces feuillets étoient adhérens au
" granit, mais s'en séparoient pourtant
" lorsqu'on les frappoit avec le marteau.
" En les observant avec soin, je vis qu'ils
" étoient composés de feuillets très-fins, d'un

" quartz blanchâtre, séparés par des couches
" plus fines encore, d'un mica jaune et
" brillant. Exposée à la flamme du chalu-
" meau, cette pierre se couvre d'un vernis
" brillant, produit par la vitrification du mica
" et le quartz demeure blanc et intact. Je
" crois pouvoir supposer que ces couches
" sont les restes d'une roche feuilletée qui
" servoit de transition entre les ardoises ou
" calcaires de la chaîne secondaire, et les
" granits de la primitive."

All that is to be said with regard to these observations is this, that they are strictly conform to the supposition of the central body of granite having been forced up among the stratified schisti, in those operations by which land was raised from the bottom of the sea, and horizontal strata changed to positions nearly vertical. We shall now see what occurred to M. de Saussure upon considering the situation of the stratified alpine bodies. It is in continuing to describe those objects with which we are now more immediately concerned.

" § 867. Après avoir fait cette observation,
" je regagnai la grande route, qui n'est au

" reste qu'un mauvais sentier. Ce sentier
" est très-sauvage dans le commencement ;
" le fond de la vallée est aride, couvert de
" blocs de granit ; le Glacier du Triolet,
" enterré sous des débris, le torrent sale et
" écumeux qui sort là d'un tas de glaces et
" de décombres, et quelques mélezes mes-
" quins et malades, parsemés au milieu de
" ces rocs et de ces glaces, présentent
" l'aspect le plus triste et ne réveillent que
" des idées de désolation et de ruine.

" § 868. Lorsque l'on a un peu avancé
" dans cette route, si l'on se retourne pour
" jeter les yeux sur le Mont-Ru, on démêlera
" quelque régularité dans sa structure : on
" verra qu'il est divisé du haut en bas par
" de grandes fissures qui le traversent de
" part en part. Ces fissures, parallèles
" entr'elles, coupent la montagne en grandes
" tranches très-épaisses, qui sont elles-mêmes
" subdivisées en tranches plus minces. . Ces
" fissures sont les profils des intervalles des
" grands feuillets pyramidaux dont cette
" montagne est composée. Ceux de ces
" feuillets qui sont les plus extérieurs, ne
" sont pas si bien séparés ; leurs sommités

"ne s'écartent que très-peu les unes des "autres, et l'ensemble de ces sommités "forme une arrête presque continue, mais "les feuillets intérieurs qui s'élevent à une "grande hauteur, ont leurs cimes separées "et forment des dents aigues et distinctes.* "Les plans de ces feuillets ne sont pas "comme ceux de l'Allée-Blanche, parallèles "à la vallée, car celle-ci court ici au sud-sud-"ouest, et ces plans au sud-sud-est, ce qui "fait un écart d'environ 34 degrés.

"Les montagnes suivantes, en avançant "vers Courmayeur, présentent une struc-"ture à peu-près semblable ; mais les plans

* Here we find a clear explanation of the appearance of those artichoke leaves, by which our author endeavours to give us an idea of the structure of those pyramidal mountains. The great mass of granite, in cooling or contracting, formed perpendicular fissures ; the action of the atmospheric elements upon those great divisions of the mass has made of them pyramidal leaves with which the great mountain is surrounded. Here the natural divisions of this solid mass have determined, as has been already observed (Part 2nd, Chapter [ix pp. 304 *et seq.*]), the present form or the directions of the greatest and least decay of the rock. [MS. note in Hutton's own handwriting.]

" des tranches semblent se retourner gradu-
" ellement pour s'approcher de la direction
" de la vallée, à laquelle elles deviennent
" enfin parallèles.

" Toutes ces couches, si du moins ce sont
" des couches, car je ne l'affirmerois pas de
" celles-ci comme de celles dont j'ai distincte-
" ment reconnu la nature, tous ces feuillets,
" dis-je, surplombent du côté de la vallée.

" § 869. Au reste, quand je dis que de
" grandes tranches de rochers, semblables
" à celles-là, ***surplombent***, il ne faut pas
" s'imaginer qu'elles n'aient aucun appui,
" elles reposent sur d'autres, et quoique
" celles-ci surplombent aussi, comme elles
" diminuent graduellement en hauteur, la
" montagne, dans sa totalité, est soutenue
" et ne surplombe point; tout est appuyé
" comme dans une voûte.

" § 870. Il seroit bien difficile de rendre
" raison des anomalies que l'on observe dans
" la situation des couches. Même dans les
" montagnes secondaires, dans le Jura par
" example, on voit des couches très-voisines
" les unes des autres dans des situations
" tout-à-fait différentes. Or, les montagnes

" primitives qui sont beaucoup plus anciennes,
" qui ont par conséquent été plus longtemps
" exposées aux agens et aux révolutions de
" tout genre, doivent nécessairement pré-
" senter des anomalies encore plus grandes.
" Et si, comme je commence à le croire, les
" montagnes dont les couches sont verticales,
" ne doivent cette situation qu'à des mouve-
" mens violens, qui ont redressé des plans
" originairement horizontaux ; il est plus
" naturel encore, que dans ce redressement
" violent, les montagnes d'une même chaîne
" n'aient pas toutes pris des situations par-
" faitement semblables."

Here M. de Saussure enters perfectly into my views, at least, so far as regards the formation of those alpine strata which have been considered by other philosophers as original bodies of the globe. This testimony, at all times most respectable, is on this occasion of the greater weight, in that upon the most mature consideration and accurate survey of the facts, M. de Saussure here changes his first opinion, if he had allowed himself to form one, before examining sufficiently the subject.





Another remarkable observation with regard to the junction of the granite with the schistus, we have in this same Vallée de Ferret. It was to lead to these observations that I have here transcribed the description of the Col Ferret, because however interesting in itself may be this view with respect to the construction of those mountains, it would not have found its place here, were it not to make the observations with regard to the granite better understood.

" § 872. En cheminant dans ces pâturages, " les yeux toujours fixés sur la chaîne primi- " tive, je vis au bas de cette chaîne des couches " semblables à des ardoises, et appliquées " contre des rocs de granit. Comme rien " n'est à mon gré plus intéressant pour la " théorie que les jonctions de montagnes de " différens ordres, je résolus d'aller observer " celle-là ; mais comme il étoit trop tard " pour la bien faire dans la même journée " j'allai coucher à Courmayeur qui en est " éloigné de deux lieues, et j'y revins le " lendemain.

" En partant du fond de la vallée, if faut

" monter pendant près de trois quarts d'heure,
" pour arriver au point où les schistes touchent
" les granits. Ces schistes, qui de loin ne
" paroissent qu'une surface mince appliquée
" contre le pied de la montagne, sont un
" amas considérable de différentes couches.
" La matiere qui compose la plus grande
" partie de ces couches est remarquable en
" ce qu'elle fait une vive effervescence avec
" les acides, et se fond pourtant très-aisément
" au chalumeau en un verre d'un verd clair,
" transparent, qui coule et s'affaisse sur le
" tube de verre, auquel on l'a soudé Sa
" couleur est noirâtre, et son grain ressemble
" à celui d'une pierre calcaire.

" Les couches de ce schiste sont entre-
" mêlées de couches d'un grès fin, peu
" cohérent, et qui se résout de lui-même
" en un sable blanc que l'on trouve en
" quantité au pied de ces mêmes couches.
" Le foible gluten qui unit ces grains de
" sable est de nature calcaire.

" Ces couches sont un peu arquées ; mais
" leur situation générale, de celles du moins
" qui sont les plus basses, est verticale à
" quelques degrés près dont elles s'appuient

" contre la montagne. Il ne peut y avoir
" aucun doute sur la situation des couches de
" ces schistes, parce qu'elles sont exactement
" parallèles aux feuillets mêmes dont ils sont
" composés. Mais ces couches sont coupées
" de part en part, et à angles droits par des
" fentes parallèles entr'elles, et qui se courbent
" toutes semblablement en descendant du côté
" du sud-ouest sous un angle d'environ 50
" degrés. Ces fentes laissent entr'elles des
" intervalles, ici d'un pied, là seulement de
" quelques pouces. Lorsqu'on voit de loin
" ces fentes, il est impossible de ne pas les
" prendre pour la division des couches de
" la pierre ; tant il est important dans ces
" recherches de voir de près et d'observer
" en détail ; car la structure intérieure de la
" pierre peut seule décider entre ces sections
" qui se croisent à angles droits, quelles sont
" celles qui dénotent la situation des couches.
" J'ai déjà dit ce que je pensois de l'origine
" des fentes qui coupent ainsi les couches, et
" j'y reviendrai encore ailleurs.*

* I have given these observations of M. de Saussure in a note in Part I, Chapter ii. [This note has been inserted in Hutton's own handwriting. The reference

"§ 873. Je distinguai, dans la transition
" de ces schistes aux granits, quatre nuances
" bien marquées.

" Les premieres couches de schiste, où
" l'on apperçoit quelque altération, prennent
" des feuillets plus ondés, plus luisans, plus
" ressemblans à du mica, mais elles ont
" d'ailleurs les mêmes propriétés.

" Les suivantes sont encore plus ondées ;
" on y voit des feuillets de vrai mica, et outre
" cela un mêlange de quartz, qui donne des
" étincelles contre l'acier, quoique la pierre
" fasse toujours effervescence avec les acides.
" On voit dans cette même pierre des veines
" d'une matiere noir, brillante, composée de
" petits rhomboïdes, qui paroissent être la
" crystallisation de la matiere même la plus
" pure du schiste ; car ces crystaux se dis-
" solvent avec effervescence dans les acides,
" sans y laisser de résidu sensible, et cepen-
" dant ils se fondent très-aisément au chalu-
" meau en un verre verdâtre et transparent
" qui s'affaisse sur la pointe du tube de verre.

" La troisieme nuance est un vrai quartz

appears to be to vol. i of the *Theory of the Earth*, p. 112 *et seq.*]

" mêlé d'un peu de mica et qui ne fait aucune
" effervescence.

" La quatrieme est un granit gris à très-
" petits grains, de quartz, de feldspath et de
" mica.

" Cette transition occupe en générale une
" épaisseur peu considérable : dans quelques
" endroits ces quatre couches, prises en-
" semble, n'ont pas plus d'un pied : cepen-
" dant le granit n'a toute sa perfection, ses
" grains ne sont bien nets et bien distincts,
" qu'à quelques pieds de sa jonction. On
" distingüe des couches dans ce granit par-
" fait, elles sont parallèles à toutes celles qui
" forment cette transition.

" Je suivis à une assez grande distance, en
" côtoyant la montagne, cette jonction des
" schistes, en sondant partout avec le mar-
" teau les banc limitrophes ; je n'observai
" point de différence notable dans la nature
" des couches, qui formoient la transition
" entre le granit et le schiste, mais je trouvai
" quelque changement dans la situation des
" bancs. En avançant du côté du sud-ouest,
" je vis les schistes, de même que les granits,
" surplomber du côté de la vallée, ici de 35,

" là même de 47 degrés. La direction des
" couches change aussi un peu. Celles qui
" sont les plus voisines du Col Ferret courent
" au sud-sud-ouest, tandis que les plus éloig-
" nées de ce même Col, courent d'environ 30
" degrés plus à l'ouest."

If I had not been acquainted with this subject of the junction of the granite and alpine schisti, I should have been inclined to think that here was an evidence of a gradation with regard to the original formation of those two bodies, when these had been deposited in form of strata at the bottom of the sea. I am, however, almost persuaded from this description that the apparent gradation, here perceived, has for cause the contact of the granite in a fluid state of fusion with the schistus which it had been made to invade. I have observed that where, from the mass of granite, there have proceeded veins into the schistus, the granite in the vein is commonly distinguishable from that of the mass, although nothing is more evident than that the contents of the vein are no other than part of the mass which has been made to flow into the disrupture of the

schistus; in like manner, the part of the granite mass which is in contact with the schistus, although the same mass, is yet distinguishable from that which is not connected with, and affected by the schistus.

Upon the whole, then, if it shall be allowed me to make this conjecture with regard to the observation of so able a naturalist, it would appear that here in the central granite of the Alps of Savoy and Switzerland, the same general fact is to be found which I have constantly observed wherever I could perceive the junction of the strata and granite masses; consequently that upon this occasion the body of granite in its present state is posterior to those stratified bodies which it had broken and invaded.

That this is truly the case, and that the granite really breaks and displaces the natural strata of that alpine country, as well as those of Scotland, will appear from the facts which M. de Saussure relates in the former volume of his journeys in the Alps. For there he gives an example, both in the Alps and at Lyons, of granite veins travers-

ing the natural strata. Now there is at present no question concerning the way in which those veins of granite had been formed; that is a subject fully discussed under its proper heads; we are only now enquiring which of the two bodies thus mingled together, is posterior to the other, having invaded it and occupied its place; and that question, in the case of a vein, is clearly decided. Therefore, granite, in this particular place where it is mixed with the stratified bodies of the earth, is evidently of a posterior formation, and is the transfused body which had broken and invaded the regular strata.

With regard to the stratification of granite in mass, I had formerly entertained the same idea with M. de Saussure, that they perhaps might be considered as stratified bodies of great thickness, consolidated by means of fusion. But since meeting with the most satisfactory evidence of granite having been made to flow in the manner of subterraneous lava, I have in some measure changed my opinion, and am rather inclined to think that the apparent stratification, which may be

perceived in any of those granite masses, may be considered as a regular separation by the contraction of the mass. I am certain of this, that in the most perfect of our subterraneous lavas, *i.e.*, our whinstone, or the Swedish Trap, there is upon many occasions exhibited the most perfect appearance of stratification, so far as it is to be judged from the external appearance, or by the separations of the rock; a particular example of this may be seen in the west side of the great insulated mass or rock of whinstone or basaltes upon which the Castle of Edinburgh is built. Here from the external appearance it is impossible to conclude any otherwise than that [in] this rock, of which we know so well the nature, were [are] regular strata of the schistus kind, in a situation almost vertical.* It is, however, no more certain, at least according to my observations, that whinstone had been made to flow in the bowels of the earth, than that the granite in

* [Hutton recognized the jointing of eruptive rocks as a result of contraction, and as distinct from true stratification even where it separates the rocks into parallel beds or strata.]

Athol and in different parts of Galloway, had done the same. Consequently, I would at least be cautious of extending stratification, which is so evident in the other alpine productions of the schistus kind, to that species of granite which appears in masses, and which from the internal structure of the body, must have been in a very considerable degree of fusion, if it had not been actually made to flow.

I will now give M. de Saussure's *resume* upon this subject of the central masses of the Alps.

" § 677. Si on veut réunir sous un seul
" point de vue toutes les observations con-
" signées dans ce chapitre, il faut considérer
" que les montagnes qui bordent au sud-est
" la vallée de Chamouni, sont composées de
" deux parties distinctes. L'une de ces
" parties est le massif non-interrompu et uni-
" forme qui s'éleve jusqu'à 7 ou 800 toises
" au-dessus de la vallée ; (*planche premiere*)
" l'autre, les pyramides ou les aiguilles
" détachées qui dominent ce massif.

" La masse uniforme inférieure est com-
" posée de roches feuilletées de différens

" genres, mais le plus souvent quartzeuses et
" micacées. Ces roches sont disposées par
" couches très-régulieres, qui courent comme
" la vallée du nord-est au sud-ouest ; elles
" sont peu inclinées vers le bas de la mon-
" tagne, mais elles se relevent graduellement
" contre le vallée, jusqu'au haut où elles sont
" exactement verticales. Ces mêmes couches
" s'approchent de la nature du granit à
" mesure qu'elles s'approchent du haut de la
" montagne ; et là, elles deviennent des
" granits veinés ou même des granits en
" masse, encaissés dans des couches, ou de
" granit veiné, ou de roche feuilletée.

" Les pyramides qui dominent ce massif
" sont de granit en masse. Elles sont
" flanquées, et même composées extérieure-
" ment de feuillets pyramidaux, qui sont
" subdivisés en couches parallèles aux plans
" mêmes des feuillets. Ces feuillets sont
" presque verticaux, et s'appuient, non pas
" contre la vallée comme les couches
" inférieures du massif, mais contre le corps
" même des pyramides. D'ailleurs, leur
" direction est à très-peu-près la même que
" celle des couches du massif. Quant au

" cœur, ou à la partie intérieure de ces " pyramides, elle paroît en quelques endroits " n'avoir point une structure réguliere, et " n'être divisée que par des fentes acci- " dentelles.

" Au reste, il ne faut point s'imaginer " que ces pyramides soient assises sur le " massif qu'elles dominent comme une " colonne sur sa base ; la situation des " couches démontre que le massif est " appliqué contre les pyramides qui ont leur " base à elles, et que ce seroit plutôt le " massif qui seroit assis en partie sur les " fondemens intérieurs des pyramides, puis- " que les feuillets de celles-ci descendent " du côté de ce massif, et semblent plonger " au-dessous de lui."

Here, in making a distinction of the central mass of granite and the erected strata or various species of alpine schisti, M. de Saussure has been at the utmost pains to inform himself that the central mass which is elevated to such a height, has its basis under those erected strata with which it is immediately connected. Now this could only happen in one of two ways ;

either the alpine schisti were superinduced upon the inclined granite in its present place; or the horizontal strata had been elevated by the rising granite. I suppose M. de Saussure's theory would lead him to conclude the first; mine again leads me to conclude the last.

Thus besides the direct proof, which I have always had in my observations, of granite in a fluid state having broken and invaded the broken schisti, we have also the testimony of this central mass of the Alps having been forced up among the vertical or much inclined schisti with which it is surrounded. Consequently here is an explanation of that appearance from whence our present naturalists have been led to conclude the originality of granite as a primitive part of our Earth, viz., that all the other strata are found superincumbent upon that mass.

CHAPTER VII.

Theory confirmed by Observations made upon the Pyrenean Mountains.

WE have now examined the nature of those two tracts of alpine country in Scotland which stretch across this island, or reach from sea to sea. It may be interesting to compare with this the observations which have been made upon the Pyrenean mountains, that tract of alpine country terminating in the Mediterranean on the one hand, and in the Atlantic on the other. For if we shall find the general features of those different tracts of alpine country to be the same, and that the most distant has had no other law in its formation than those which are observed in every individual, we shall have reason to conclude that there is no other rule to be observed, and that the explanation of one tract of alpine country will serve to explain the general structure of all the alpine countries of the Earth.

The *Essai sur la Minéralogie des Monts Pyrénées** gives a very instructive view of the composition of those mountains from the one end to the other. It is that survey which is to serve as the ground on which we are to reason, and from those facts we are to draw certain conclusions tending to support the present theory, and explain those general appearances of alpine countries.

According to the present theory, there are three things essential in the formation of land, or for the production of continents; these are, first, the collection of materials

* [This quarto volume appeared at Paris anonymously in the year 1781. The imprimatur of the Royal Academy of Sciences, signed by Condorcet, states that D'Arci, Lavoisier and Desmarest had reported on a work by M. l'A. P . . . which the Academy deemed worthy of its patronage. The author was afterwards made known as the Abbé Palassou of Pau. Hutton has in this chapter contented himself with a brief outline of the evidence furnished by the Pyrenees towards his theory. Had he wished he might have found much illustrative detail in the Abbé's pages. The reader of Palassou's work may, indeed, be excused for expressing surprise that Hutton did not make fuller and more definite use of it than he has done.]

deposited in the bottom of the sea; secondly, the consolidation of those incoherent masses; and lastly, the erection of those horizontal strata into the place of Land. We are now to show that these three operations have taken place, or had been employed in the production of that tract of alpine country which lies between France and Spain, and which has been so carefully examined.

With regard to the first, that is, the original collection of the materials of which these mountains in general have been formed, it must appear that this had been the alluvion and detritus of a former Earth, and that these materials had been deposited in the bottom of the ocean. For the mass which we are now considering, is composed of regular strata in which there is every mixture of siliceous, calcareous and argillaceous substances, with the various accidents of ferruginous admixture; from whence it appears that those variously alternated strata had been gradually formed by the various superposition of materials deposited in water. But not only does it appear that they were water-formed strata, it is also demonstrated

theory, is found to correspond perfectly with the recorded appearances in this survey of the Pyrenean mountains. Every variety of inclination, from the two extreme positions, is found, although the most common, according to this author, is the inclination of 30°.*

The strata of the Pyrenees being supposed as inclined, in consequence of having been elevated, and as elevated in consequence of having been forced up from below, we may now consider how far this reasoning will correspond with natural appearances, so far as regards the mass of granite which is generally found serving as a basis to the erected strata in the alpine regions, and

* [See p. 136 of the *Essai sur la Minéralogie des Monts-Pyrénées.* Palassou believed that the inclined position of the strata was original and due to their deposition on the steep sides of the central core of granite. Yet he gives a series of twelve plates showing that the limestones of these mountains have not only been tilted up at high angles, but have been placed on end, and have in some places been bent, plicated and twisted. They are represented in several places as lying horizontally on granite, or leaning against that rock at right angles. Their plications are shown to extend through the whole body of a mountain.]

which, without any just foundation has been supposed as the solid mass of the globe, on which the strata had been originally deposited.

Let us suppose the long ridge of the Pyrenees, which runs from east to west, to have been erected by the forcing up of a fluid mass from below, the general inclination of the superincumbent beds, in that case, would be found lying either from north to south [or from south to north], according to the side of the ridge on which they happened to lie ; that is to say, upon the north side of the elevating mass, the beds would lie in general with their heads inclined to the south and dipping to the north, although frequent exceptions would occur, when they would rise and dip in the contrary direction, as forming subordinate ridges in which the opposite inclinations might be found.

If we now have reasoned justly, and if the Theory has been founded upon truth, the general direction* of the inclined beds of the Pyrenees should be from east to west, and not from north to south ; and the general

* [That is, the strike.]

dipping of those beds, upon the north side of that alpine ridge, should be to the north, the strata rising towards the south or summit. But this also corresponds with the general views or observations of our author ; consequently from the natural appearances of this side of the Pyrenean mountains, the Theory is confirmed, while those appearances are considered as being explained.

We shall thus find that this mass of granite which in many parts is found under the inclined strata, and which in other parts forms the summits of the mountains, is that very mass which had been forced in a fluid state to raise the superincumbent masses of stratified matter, to which the granite is observed to serve as basis.

We have now only further to observe, that the mountains, according to this theory, should have been much degraded, by the effects of time, or operations of the elements in dissolving mineral substances and decomposing solid rocks ; for all the granite mountains, which now are bare, have been covered by the ablution of the decayed strata, with which the summits of those

granite masses had been once encompassed. Now the bare inspection of those mountains, as well as those of every other alpine region, will sufficiently countenance this supposition; and the immense quantity of sand and water-worn gravel, with which the lower country of the north of this alpine ridge is covered, must be joined as affording the most complete evidence of that fact.*

* [Some of Palassou's plates supply impressive proofs of the denudation of the granitic core of the Pyrenees, the splintered granite sometimes rising into the peaks and elsewhere underlying buttresses and isolated needles of limestone. In his maps he notes the wide spread of detrital material in the valleys and plains to the north of the mountains.

It may be remarked here that the Abbé, though mainly intent on the rocks of the mountains, kept his eyes open to the physiography of the region. He noted for instance that the size of the valleys is always proportionate to the volume of water which they receive; and he mentions that for the most part it is only the greater or less hardness of the rocks that gives rise to any exceptions to this general law (pp. 131, 232). He believed that the valleys were the work of the torrents that flowed in them, and he pointed to the fair and ample vale of the Garonne as having been formed by that river (p. 226).]

CHAPTER VIII.

An illustration of the Theory from the Natural History of Calabria.

AFTER finishing this part of the work, I read the Chevalier de Dolomieu's memoir upon the Earthquake of Calabria.* In this dissertation there is contained some very interesting geological observations. I think it will be doing natural history a service to bring those observations into review. I shall thus endeavour to illustrate the present Theory, as well as to explain certain natural appearances.

This excellent naturalist puts one in possession of the countries which he describes, countries which he has surveyed with so much industry, and of which he gives the natural history with a learning and perspicuity that does honour to his talents and his science.

* [*Mémoire sur les Tremblemens de Terre de la Calabre, pendant l'Année* 1783. Par le Commandeur Déodat de Dolomieu. Rome, 1784.]

Having such good authority for matters of fact, I would wish still to multiply examples, and to lay before the eyes of learned men the operations of nature; operations which have preceded every mark of history in countries where history has done most credit to the memory of man.

The purpose now in view is to show the former state of things upon the surface of this Earth, from that which having remained, gives a step whereon to found a rational conclusion concerning what had been. But though those operations which we are to trace, are by far too slow to be perceived in the immediate effects, they are nevertheless to be ascertained, in reasoning upon principles which are so evident as not to leave a doubt. Such is the dissolution of calcareous earth by water, at least when exposed to the influence of the atmosphere; such is the decay and resolution of rocks exposed to the day; and such is the destructive operations of the waves, when great bodies of water are agitated by the wind.

It is true that the light in which M. le

Chevalier de Dolomieu views some particulars in this subject of geological speculation, differs considerably from that in which it appears to me. No matter; with regard to philosophy, it is indifferent. For, as neither of us desire that others should believe implicitly upon the authority of our conclusions; and both of us leave others at liberty, in giving the grounds of our particular suppositions, nothing can happen more advantageous for science than the liberal discussion of those different opinions.

There are two parts of the present Theory to which may be applied this valuable piece of natural history. The one of these respects the mineral operations* of the globe; the other, again, has reference to those operations which take place upon the surface of the Earth, and thus characterize it as different from the mineral regions. Let us now consider these in their order.

The Chevalier de Dolomieu has given good reason for believing that the granite rock, which appears in the mountains of

* [The underground or hypogene operations.]

Calabria, runs north along the course of the Appenines, but is concealed under the calcareous strata, by which this primitive rock (as it is called) of granite is covered. This able naturalist, who has so accurately examined Sicily and the Lipari Islands, supposes that this chain of mountains (which, running lengthways through Italy, describes a curve in passing through Calabria), has been continued or passes under the sea from Cape Dell'armi in Italy to Taormina in Sicily, and there is found in the Neptunien mountains, which are of the same nature and follow the same direction.

This may be considered as the general state of the case; and now we are to examine how far this state of things justifies either the general opinion of naturalists on the one hand, or the present Theory on the other.

The first of these supposes that, upon a ridge or chain of primitive mountains submersed in the ocean, there had been deposited strata of sand and marine calcareous objects, which were afterwards indurated and consolidated, so as to form

the strata which we see now superincumbent upon those masses of granite; but neither is the consolidating operation explained in that system of geology, nor the changed place or situation of things in any manner understood.

The second, again, supposes that these strata of loose materials, collected at the bottom of the sea, had been indurated and consolidated by means of heat and fusion, and had been forced from their original place in the bottom of the sea, by a subterraneous power, or by matter interjected between them and the solid globe; thus disturbing their regularity and changing their situations.

Those two different theories have only one thing in common; that is, that they suppose the strata, which are now found superincumbent on the granite, to have been originally formed at the bottom of the sea, where the various materials of which they are composed had been deposited. The theory which supposes primitive mountains admits of this fact; but this fact is the only part of that theory that has any shadow of

proof. There is as yet nothing in natural philosophy, no more than in natural history, by which either the originality of the supporting masses may be countenanced, or the induration and consolidation of the superincumbent strata can be explained. Nor is there any manner of supposition or rational conjecture with regard to the changed shape and position of those strata; nor an attempt to explain how those strata, which had been originally deposited at the bottom of the sea, are now above its surface. On the other hand, the present Theory has attempted to explain all this upon the principles of natural philosophy, carefully compared with the various appearances of the mineral regions, and perfectly supported with natural history, so far as every operation, required in the production of our mountains and our land, has been actually observed, as a thing really taking place in this world, and therefore not a thing created by the imagination.

But particularly with regard to the granite mountains, it has been shown, from all the natural history that I am master of, that

these had been masses of melted matter projected or diffused below the strata of the Earth; that those strata had been violently broken and injected by that fluid mass; and that probably this had been the means by which those strata had been elevated above the level of the sea.

Here is now an opportunity of comparing this theory with the natural history of Italy, which has been so particularly described by the Chevalier de Dolomieu in his *Mémoire sur les Tremblemens de Terre de la Calabre;* and I would wish to give all the light in my power to a subject so interesting to the theory of the Earth.

After describing the mountains which include what is called the plain of Calabria, our author thus proceeds:—

" Les Apenins apres avoir traversé l'Italie,
" en ne presentant par tout qu'une suite de
" montagnes calcaires, soulévent ici leur
" tête, et montrent à decouvert le granit et
" la roche feuilletée, qui forment, à eux
" seuls, l'extremité de cette longue chaine.
" Ces substances que l'on regarde comme
" primitives, rélativement à la formation de

" toutes les autres, au-dessous des quelles
" elles sont presque toujours placées, sem-
" bleroient offrir une base inébranlable ; et
" les montagnes qu'elles constituent, péne-
" trant par leurs racines jusqu'au centre du
" globe, devroient être exemptes du toute
" vicissitude ; c'est cependant à leur base,
" qu'ont été ressenties les secousses les plus
" violentes, et elles même n'ont pas été
" exemptes des mouvemens convulsifs, qui
" ont détruit tout ce qui étoit à leurs pieds.

" Toute la partie des Apenins, qui domine
" le fond de la plaine, et dont quelques
" sommets, ou grouppes plus élevés portent
" les noms distinctifs de Monte Jejo, Monte
" Sagra, Monte Caulone, Monte Esope,
" Aspramonte, etc., est formée presque en-
" tierement d'un granit dur, solide, composé
" de trois parties, quartz, feldspath blanc, et
" mica noir. C'est presque le seul genre de
" pierre, dont on trouve les débris au pieds
" des montagnes ; c'est le seul que roulent
" les torrens ; et c'est celui dont sont bâtis
" tous ceux des édifices de la plaine, dans
" lesquels on a employé des materiaux
" solides. Sur quelques masses de ce



" granit, sur la croupe de quelques mon-
" tagnes et sur quelques sommités, sont
" attachés quelques bancs de pierres cal-
" caires, qui paroissent comme les restes
" d'un revêtement plus considérable, que le
" tems ou les eaux ont détruit. On trouve
" aussi sur quelques sommets des roches
" de corne et des schorls écailleux (horn-
" blende); on en voit des fragmens dans
" les ruines de Terra Nova, Opido et
" Santa Cristina." *

" Les bras des Apenins, que j'ai dit
" s'étendre à angle droit pour former un
" corps de montagne ou un promontoire
" terminé par les caps Zambrone et Vaticano;
" a également pour base et pour noyeau le
" granit; mais cette roche n'y est pas
" partout également à decouvert. Elle
" paroit à nud dans les escarpemens qui
" accompagnent la coste, entre les caps
" Zambrone et Vaticano; elle y est en
" masses énormes, dans les quelles je n'ai
" jamais pu decouvrir ni couches, ni ordre
" simétrique. Ce granit est très dur; son
" grain et sa composition sont les mêmes

* [pp. 19, 20.]

" que celui des montagnes, qui occupent le
" fond de la plaine. On y voit de grandes
" taches parallépipedes, produit d'une crys-
" tallization confuse, faite par une espece
" de précipitation."*

" Ce promontoire, que je nommerai de
" Tropea, à cause de la Ville qui est bâtie
" au-dessous entre les deux caps, va en
" retrait depuis sa base jusqu'à son sommet,
" et il presente quatre petites plaines,
" prolongées d'un cap à l'autre, en terrasses
" comme les marches d'un amphithéatre, et
" separées par des coteaux rapides. On y
" suit le gradation des matieres dont le
" corps de la montagne est composé. Le
" granit solide forme le premier échelon;
" au dessus, est un très grande épaisseur de
" granit décomposé, dont les grains ont
" perdue leur adherence, et qui se détruit
" au moindre choc. Dans cette espece de
" roche pourrie, les eaux ont ouvert de
" profonds ravins, surtout dans la partie du
" cap Zambrone, ou elles ont fait de cou-
" pures effrayantes, qui pénétrent toute
" l'épaisseur de la montagne; mais dont

* [p. 25.]

" les bords, quoique très rapides, ont pris
" cependant un peu de talus, n'ayant pas,
" comme dans la plaine, une croute solide
" qui soutienne les terres, et qui s'oppose
" aux éboulemens. Sur le granit en décom-
" position est une couche de plusieurs
" centaines de pieds d'épaisseur, formée
" d'un beau sable quartzeux blanc, dans
" lequel j'ai trouvée beaucoup de corps
" marins et surtout une grande quantité de
" superbes échinometres. Enfin la partie
" la plus haute de cette montagne, celle qui
" forme son sommet, est une pierre calcaire
" blanche à bancs horisontaux. Ce sommet
" aplati, sur lequel domine la seule mon-
" tagne calcaire, isolée, ditte Poro, qui
" porte les ruines d'un ancien château,
" forme une espece de plaine inégale, qui
" se prolonge jusqu'à la grande chaine, en
" passant dessous Monteleone. Mais ce
" haut plateau ne partage pas la fertilité des
" plaines et des coteaux qu'il domine.

" La ville de Tropea, située au bord de la
" mer, vers la base du Promontoire, est asise
" sur un rocher de granit, qui s'avance un
" peu dans la mer qu'il domine. La partie

" extérieure de ce granit est révêtue d'une
" roche calcaire sabloneuse, foiblement aglu-
" tinée et remplie de corps marins. Une
" concrétion calcaire semblable est adherente
" au granit dans quelques autres endroits de
" la coste.

" Les flancs de cette montagne, du côté du
" sud, dans la partie ou est située Nicotera,
" presente encore à découvert un superbe
" granit à gros grains, dont les blocs sont
" très considérables et dont on pourroit faire
" de beaux ouvrages. Dans la partie supéri-
" eure le granit se décompose, mais il est
" moins friable que celui des environs de
" Tropea. Il est traversé par des veines ou
" filons de feldspath micacé, dont une partie
" approche de l'état du petuntze de Saint
" Yrié en Limousin, et l'autre se change en
" argille.

" En prolongeant cette même face de
" montagne jusqu'à Miletto et Vallelunga, le
" granit solide paroit plonger sous terre, pour
" ne laisser paroitre que le granit en décom-
" position, un sable quartzeux, et une argille
" blanche micacée, assez grasse et ductile,
" qui pourroit être encore un produit de la

" décomposition du feldspath. Ces matieres
" forment les coteaux adossés à la montagne
" dans lesquelles les eaux pénétrent facille-
" ment et ouvrent des gorges et des vallées
" profondes. La Ville de Miletto étoit bâtie
" sur ces coteaux.

" Sur le revers de cette montagne, c'est-à-
" dire sur sa croupe du côté du Nord, depuis
" le fleuve Angitola jusqu'au cap Zambrone,
" le noyau paroit être un mélange de granit,
" de roches feuillettées et glanduleuses, et
" de roche de corne noire, parmi lesquelles
" domine une roche noiratre micacée conten-
" ant une quantité immense de grenats
" crystallisés confusement, et mêlés quelque-
" fois de pyrites.* Ces grenats par leur

* " Cette roche feuilletée et micacée, contenant des
" grenats, prouve que ces parties constituantes ont été
" petries ensemble, et ont été precipitées en même tems
" du milieu du fluide qui les tenoit dissoutes. Dans
" quelques unes, le fond de la pierre est comme une
" pâte de la nature du grenat, qui enveloppe le mica.
" Ailleurs le grenat a sa forme crystallisée particuliere,
" et est enseveli dans le mica qui le contourne."
[p. 28.]

This argument of the Chevalier de Dolomieu is
certainly just, so far as concluding that those two or



" trituration ont formé un très beau sable " rougeatre, qui se trouve au bord de la mer, " et qui est presque entierement composé de " leur fragments. Dans la partie supérieure " de la montagne, au dessus des roches que " je viens de désigner, il y a des pierres cal- " caires micacées, et enfin des pierres calcaires " coquillaires.

" La Ville du Pizzo, adossée à ces roches " noires schisteuses et granitiques, est bâtie " sur un rocher, qui s'avance dans la mer, et " qui est enveloppé dans sa partie extérieure,

three bodies had been formed together; but I cannot admit that here is any mark by which we should know that those different substances had concreted by separating from a fluid medium in which they had been dissolved. On the contrary from the analogy of similar bodies, it is certain that, in this case, they had concreted from a fluid state of fusion. [The progress of observation has not justified this dogmatic certainty of the illustrious author. How for instance would he have explained the occurrence of garnets in the midst of perfectly recognizable fossil shells? The opinions which he combated have been equally disproved. The modern theory of Metamorphism curiously combines some of the leading ideas both of the Neptunian and Plutonian systems. For the germ of this theory see vol. i, pp. 375, 376.]

" par une aglutination de sable calcaire et
" quartzeux, mêlé de corps marins. J'y ai
" trouvé de très beaux échinites. Cette
" espèce de concretion, formant une masse
" peu solide, est presque semblable à celle de
" Tropea ; elle est adhérente à d'autres
" rochers schisteux de la même montagne.
" Elle se recouvre, par le concours de
" l'humidité, d'une espèce de croute ou
" mousse noiratre, qui a trompé l'œil de M.
" le Ch. Hamilton ; il a cruy voir un tuf vol-
" canique. Je puis assurer, apres l'examen
" le plus réfléchi, et apres des recherches fort
" exactes, que, dans toute cette partie de la
" Calabre, il n'y a pas le moindre vestige des
" produits du feu.

" Pour suivre l'examen des montagnes, qui
" entourent la plaine, il me reste à déterminer
" la nature du corps de montagne, qui se
" termine en face de Messine, et qui borde
" la coste, depuis le Pezzo jusqu'a Bagnara,
" en suivant le contour du promontoire, qui
" par son étranglement a formé le Phar, et
" contre le quel, dans la partie du Nord-
" ouest, est bâtie la ville de Scilla. Le
" noyau est encore ici un granit recouvert de

" roches feuilletées et micacées ; il est sur-
" monté dans quelques endroits par des
" pierres calcaires et pierres sabloneuses
" tendres.

" Le schiste micacé et le schiste argilleux
" dominent dans les montagnes qui environ-
" ent les riches campagnes de Regio, et qui
" se prolongent jusqu'au cap Spartivento.
" Ces schistes sont traversés par des filons
" de quartz, et des filons metalliques. On y
" avoit tenté l'exploitation d'une mine de
" plomb tenant argent, qui ensuite a été
" abandonnée.

" Le revers des Apenins, c'est-à-dire, la
" partie qui regarde l'est, presente un aspect
" moins décharné, moins aride que la face de
" l'ouest. Les pentes sont moins rapides, et
" les croupes sont couvertes de bois. Les
" montagnes paroissent moins hautes, par ce
" qu'elles sont acompagnées de montagnes
" du second ordre, et de collines qui descend-
" ent jusqu'à la mer, dont le centre de la
" chaine est beaucoup plus rapproché, que
" dans la partie opposée. Cette coste offre
" une suite de sites variés, et de positions
" charmantes et pittoresques. Les cam-

" pagnes y sont d'une extrême fertilité ; il y
" a peu de plaines, mais les vallons sont
" délicieux ; les coteaux sont couverts de
" meuriers et d'arbres fruitiers, et les oliviers
" y étant moins nombreux que dans la partie
" de l'ouest, la verdure y a plus de fraicheur
" et d'agrément. Le centre ou le noyaux
" des montagnes secondaires et des collines
" est solide ; le schiste et la pierre calcaire
" y regnent ; ils y sont traversés de quelques
" filons metalliques.

" La partie de la chaine des Apenins, qui
" passe à travers l'isthme ou l'étranglement
" formé par les golphes de Sainte Euphémie
" et de Squilace, est encore un composé de
" granit, de roche feuillettée et de schistes,
" couverts en quelques endroits par la pierre
" calcaire ; ce n'est qu'au dela de Nicastro
" et de Catanzaro, que toutes ces substances
" se cachent sous la pierre calcaire, qui leur
" est substitutée dans toute la partie supéri-
" eure de cette chaine, pour ne plus se
" montrer que dans les laves et déjections
" du Vesuve, et dans les productions
" volcaniques de la Campagne de Rome
" et de la Toscane : le feu des volcans

" allant les arracher à une très grande
" profondeur.

" Il résulte de cette examen général, que
" la Calabre a, presque partout, le granit
" pour fondment: que c'est sous cette base,
" qui paroit inébranlable, qu'étoit le foyer
" des tremblemens de terre; ou au moins,
" que c'est dessous ces matieres solides,
" qu'ont agi les forces qui ont occasioné
" les grands ébranlemens des surfaces; que
" dans aucune partie de cette province, il
" n'y a vestiges de volcans; que je n'ai
" trouvé aucunes matieres altérées par les
" feux souterrains, ni dans les montagnes,
" ni dans les pierres roulées par les torrens;
" qu'il n'y a dans cette province, ni laves,
" ni tufs, ni scories d'aucunes especes. Je
" n'ai vu, dans l'intérieure de la plaine, que
" deux sources d'eaux hépatiques froides;
" il y a une source abondante d'eau thermale
" sulphureuse, auprès de sainte Euphémie,
" au dela de la presqu' isle; mais je ne puis
" regarder, ni les unes, ni les autres, comme
" indices de feu, puisque la décomposition
" spontanée des pyrites suffit pour les
" produire. J'insiste sur cet objet pour

" détruire l'opinion de ceux, qui supposent
" des feux recellés sous cette province. Ils
" s'y feroient connoitre par des phénomenes
" moins équivoques, s'ils y existoient ; il n'y
" a dans la plaine, et dans les montagnes
" qui l'entourent, au moins dans celles qui
" en forment le quadre, ni mines ni matieres
" sulphureuses, ni bitumes, quoique les his-
" toriens du pays prétendent le contraire.
" Le granit se montre à decouvert, dans
" presque toute cette ceinture, et le sol
" inférieur n'est qu'un composé d'argille,
" de sable, et de cailloux."*

Perhaps my imagination may be hurried away by the prejudice of system, to complete by fancy the scene which is left imperfect in the description ; this may happen notwithstanding every effort to guard against the delusion. But I am sure there is not in all the natural history which is here so accurately given, anything which could favour the supposition that the stratified rocks, which appear above the granite, had been formed by sand and loose materials deposited upon original mountains in the

* [pp. 25-33.]

sea; unless, in order to be satisfied of that fact, we are to content ourselves with this, that the one of those two things is found resting upon the other. But this superincumbence of the strata upon the irregular masses of granite, follows equally, whether we suppose the granite mountains first formed, and then the strata superinduced upon them, or the strata first formed, and then the masses of granite forced up among those elevated strata. Therefore we will be allowed to draw this conclusion, that here is no absolute proof, either of the one supposition or the other; and that before we can decide the question with regard to the order of those things, we must enquire more minutely into the nature of those masses, the causes of their induration or consolidation, and the various shapes in which the granite and the stratified bodies are found connected together.

It may be asked how far the appearances here detailed are explainable in all their parts by the present Theory, or are perfectly corresponding with those from whence the theory of granite injections had been

formed. In all the places where I have seen the granite and the alpine schisti meet together, I have found clear demonstration of the granite masses having been injected in a fluid state among the broken and disordered strata. It now remains for M. le Chevalier de Dolomieu to say how far he found similar appearances in those places where he has given us to understand that there is a mixture of those different things; and where in all probability some appearances may be found by which this important question might be decided.

We now come to the second part proposed, which is to compare with this natural history of Calabria the present Theory respecting the degradation of the surface of the Earth, by the decay of rocks and the attrition of bodies moved by water flowing in the rivers and agitated with the wind.

In describing the height which surrounds the plain of Calabria, our author thus proceeds—

" La pente de ces montagnes est très " rapide, leur sommet est décharné, et l'accez

" de plusieurs est impraticable. Elles ont
" cet aspect de viellesse, et de dégradation,
" que l'on observe dans toutes les montagnes
" du même genre. Sur le prolongement de
" leur base, se sont établis successivement,
" comme par depôt et sur une très grande
" épaisseur, des couches de sable quartzeux,
" de galets, d'argille grise et blanchatre, et
" de grains de feldspath et de mica proven-
" ants de la décomposition des granits. Le
" tout est mêlé de coquilles et de fragmens
" de corps marins. Cet amas de matieres, qui
" n'ont point de liaisons entr'elles et qui sont
" sans consistence, paroit être un depôt de
" la mer, qui poussée par les vents d'ouest,
" a entassé au pied de ces montagnes, contre
" lesquelles elle venoit battre dans un tems
" fort antérieur à l'état actuel des choses,
" les detritus des sommets supérieurs et les
" corps que son mouvement de fluctuation
" lui faisoit apporter de fort loin."*

Afterwards, in a note, our author says—
" On pourroit supposer que dans les tems
" anciens, les mouvements de la mer, de
" l'ouest à l'est, étoient plus considérables

* [pp. 20, 21.]

" et plus frequens, que dans la partie opposée;
" puisque d'un côté de la chaine, elle a
" entassé, au pied des montagnes, beaucoup
" de sable et de detritus des sommets
" supérieurs, dont elle a formé ce que j'ai
" décrit sous le nom de Plaine; pendant
" qu'a l'est, elle baigne encore immédiate-
" mént le pied des côteaux, sans y avoir
" formé d'attérissement."*

Here is a theory, hazarded by our author, which I am by no means inclined to subscribe. M. le Chevalier de Dolomieu supposes the sea, in a former period of time and state of things, to have washed the sides of those granite mountains, the detritus of which are here accumulated, in forming very high land, although called the plain; and that this sea had at the same time lodged marine objects among those ruins of the mountains, objects which were proper to the sea itself, and which it had travelled perhaps from afar. According to this manner of reasoning, the sea, instead of gaining upon this land in general, or destroying the coast which is opposed to its fury, must be

* [p. 31.]

retreating from the land in sinking below its former level. Now though this appearance of the gradual retreat of the sea from any coast, may be explained by the gradual elevation of that land from the sea, by those agents that made it first appear above the surface of those waters in which it had its birth, yet this elevating power is an operation to which we are never to have recourse except when appearances necessarily lead to that conclusion. But this is not the case at present, with regard to those appearances of immense detritus accumulated at the foot of mountains washed by the hands of time beyond conception; appearances which, so far as I am able to conjecture from this description, may be explained in another manner, more agreeably to the natural progress of our land, and perhaps more consistently with collateral circumstances, with which they may be found attended.

On all hands, it is necessarily required to suppose some ancient state of things, different from what appears at present. If we suppose the land of Italy to have been some hundreds of feet below the level at which it

stands just now; and if we suppose the mountains then proportionably higher, we may thus explain the present appearances of things, by having, in the natural operations of the Earth, the surplus of the present mountains worn down, and their travelling materials buried in the sea, along with marine bodies thrown in upon that coast. In this manner may have been collected that immense detritus of which the present country of Calabria within the mountains is composed. But then it must be necessary to raise up Italy from the bottom of the sea, so as those materials which had been collected in the water of the Mediterranean might be elevated to the height of the country which is here described. Now the question is, how far it is more natural, on the one hand, to suppose all this, or on the other, that the Sicilian ridge at Messina had been formerly continued through the sea to join the point of Italy at Tropea, while those two countries were also connected at the straits. A lake of water might thus be formed, in which the plain of Calabria should be deposited upon its present level,

from the detritus and alluvion of the mountains which certainly have been degraded for that purpose. We have but further to suppose, that in course of time, the barrier towards the sea by which the waters of this lake were retained, had been removed by the efforts of the waves upon that coast, or any other cause. In that case, the present appearances of things, so well described by our author, will be perfectly understood. Let us see what he further says upon the subject.

"Ce depôt, d'abord horisontal du nord au
" sud, et incliné de l'est à l'ouest, comme il le
" paroit par la direction des couches, a été
" ensuite modelé, soit par les courans de la
" mer elle même, soit par les dégradations
" des torrens supérieurs, et il a formé cette
" suite de collines, de vallées et de plaines,
" qui surbaissées les unes aux dessous des
" autres, vont se terminer par une plage
" basse sur le bord de la mer. Les progrès
" et les depouilles de la végétation, et
" d'autres causes que je ne connois pas, ont
" établi sur cette base mobile, une couche de
" terre végétale, argileuse, noire ou rougeatre,

" très forte, très tenace, et qui a depuis deux
" jusqu'à quatre et cinq pieds d'épaisseur.
" Cette espèce d'écorce donne un peu de
" solidité à ce sol, qui se trouve encore lié
" par les racines nombreuses des arbres
" qui poussent à sa surface. Ces racines
" pénétrent très profondément, pour aller
" chercher l'humidité, que conserve toujours
" la partie inférieure de ce sable.

" Cette partie de la Calabre est arosée par
" les eaux des montagnes supérieures, qui
" sont très abondantes pendant l'hyver et le
" printems, et qui, apres les pluies et la fonte
" des neiges, se precipitent par torrents dans
" la Plaine. Elles entrainent alors tout ce
" qu'elles trouvent sur leur passage, et
" lorsqu'elles ont commencé à ouvrir un
" sillon dans la terre végétale, elles appro-
" fondissent aisément leurs lits dans un sol
" qui ne presente plus aucune résistance.
" Elles creusent ainsi des gorges d'une
" profondeur extrême, quelquefois de six
" cents pieds. Mais leurs encaissements
" restent toujours escarpés et presque per-
" pendiculaires; parceque la couche supéri-
" eure, entrelassée de racines, retient les

" terres qui sont au dessous et les empêche
" de s'ébouler pour prendre leur talus. Tout
" le pays est donc sillonné et coupé par des
" ravins, plus ou moins larges et profonds,
" où coulent de petites rivieres, dont les eaux
" se reunissent pour former les deux fleuves
" Metramo et Petrace. Ces fleuves débouch-
" ent dans la mer à peu de distance l'un de
" l'autre, apres avoir traversé la partie in-
" férieure de la plaine, dont leurs attérisse-
" ments ont augmenté et augmentent encore
" journellement l'étendue, comme on peut
" l'observer a leur embouchure. Leurs rives
" qui sont de la plus grande fertilité et qui
" sont susceptibles d'être arosées, ne sont
" pas cependant la partie la plus cultivée de
" ce beau pays ; on n'ose pas les habiter à
" cause du mauvais air.

" Cette dégradation operée par les eaux
" a produit deux effets. Elle a d'abord
" formé un très grand nombre de gorges
" et de vallées, qui ont divisé et morcellé
" l'ancien sol. Quelques unes de ces vallées
" sont devenues susceptibles de culture ; les
" autres s'y refusent encore, parceque les
" inondations de chaque année les recouvrent

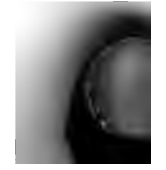
" de sable, de gravier et des débris des
" terreins supérieurs. Presque toutes sont
" encaissées par des escarpments très hauts,
" semblables à des murs ; quelques uns de
" ces encaissements ayant acquis un peu de
" talus, se sont couverts d'arbes qui contri-
" buent à leur solidité ; mais aucuns n'ont la
" pente nécessaire pour soutenir les terres
" sur une base proportionée à leur hauteur.
" Les parties de l'ancienne plaine, qui n'ont
" pas été dégradées par les eaux, sont
" restées au dessus de ces vallons, et y
" forment des plateaux, dont les hauteurs se
" correspondent, qui sont plus ou moins
" étendus, et qui sont toujours environnés
" des ravins que je viens de décrire.
" Quelques uns de ces plateaux, parfaite-
" ment isolés, ressemblent à ces montagnes
" calcaires à sommet applati, que l'on voit
" souvent dans les plaines, et dont les
" couches correspondent à celles des haut-
" eurs voisines. La nature a pu, par un
" mouvement violent de fluctuation dans la
" masse des eaux de la mer, opérer ancienne-
" ment sur les sols à noyaux calcaires, plus
" mous qu'ils ne le sont aujourdhui, ce qu'elle

" fait sous nos yeux dans les plaines sab-
" loneuses de la Calabre."*

It is with great diffidence that I would oppose the opinion of so enlightened a naturalist ; an opinion taken upon the spot, and apparently unaffected by any particular system by which the natural philosopher had been warped in his understanding. But from this description of the Chevalier de Dolomieu, I think there is sufficient ground to suppose that the formation of the great mass of travelled materials which compose the country called the plain of Calabria, might almost, if not perfectly, be explained.

The rock and mountains from the destruction of which we are to suppose this mass of travelled materials to have proceeded, consist of granite, of alpine schistus, of limestone, and of a compound species of strata which our author has described in the following terms :—" une roche calcaire sabloneuse, foiblement aglutinée et remplie de corps marins." In the amphitheatre between the capes Zambrone and Vaticano, this travelled soil is described as consisting,

* [pp. 21–23.]

first of the detritus or decomposition of granite, secondly of a bed of beautiful white sand, some hundred feet thick, in which the Chevalier says, " J'ai trouvé beaucoup de corps marins, et surtout une grande quantité de superbes échinometres." How far this bed may be supposed to have proceeded from the decay of those sandy calcareous strata which have certainly covered the granite mountains, and of which the proof still remains in the lower parts, I submit to the Chevalier for decision. One thing is certain, that were I, from the description which the Chevalier has given us of the solid parts, to have determined, *a priori*, what might be reasonably expected as forming that mass of travelled materials which compose the plain, I must have given it in similar terms to those which the Chevalier has employed in describing this subject from actual observation.

I do not here seek to support an insufficient theory with a precarious argument: but would wish to have every means employed, by which truth might be made to appear. It is no ways necessary that I

should be right in this conjecture with regard to the formation of the plain; the mountains are degraded, the ruins of those mountains are amassed at their feet, and the sea is making constant encroachments on the coast, while those travelled materials are gradually protruded into the sea. Here are facts which are indisputable; and by these operations great changes may be made upon the surface of the Earth. But how far, in the present appearances of things, we shall find the operation of the mineral kingdom, elevating land, combined with the work of time, employing the atmospheric influences in levelling the surface of the Earth, is a subject which would require, at least, the most delicate investigation to analyze.

The supposition, of those loose materials having been collected in their present place and situation with respect to the level of the ocean, requires less than to suppose them to have been collected below the surface or at the bottom of the sea. If we are to adopt the first of those suppositions, there is nothing required but that which cannot be denied; that is, that the summits of the land

had been much higher above the sea, as well as its extent much greater than at present. Consequently by the operation of the air and water from above, and that of the sea below, the mountains were lowered and part of the land upon the coast destroyed. The Plain of Calabria might thus be produced in the operations of time, changing the figure of the earth, without supposing the solid land to move, nor the level of the sea to change. But if we are to adopt the second of those suppositions, we must either suppose the mountains to have been moved by a subterraneous power; or we must suppose the sea to have moved, whether in a gradual retreat, by which means the materials deposited in it may have been made to appear more than 600 feet above its surface, or by some violent convulsion in which the sea should be made to raise up from its bottom, or the shore, all those materials which compose the plain, and deposit them upon the solid land, in again retreating to its former level. Here would appear to be the only suppositions which we have it in our choice to make; and naturalists have but to

determine, from the actual state of things carefully examined, which of those three possible ways of forming such a country had been employed.

But whatever shall be decided with regard to that point, I would beg the attention of naturalists to another subject. There is not to be observed in all this enormous depth of travelled materials, the least appearance of concretion, petrification or consolidation ; no minerals formed in this mass, and no interstice or cavity filled with matter proper to the mineral kingdom. I presume this upon the description now examined ; such a naturalist as the Chevalier de Dolomieu could not have had the opportunity without seeing the appearance ; and he could not have seen this memorable fact without mentioning it in the most express terms.

Here is a phenomenon worthy of our attention, as affording great subject matter for reflexion. Will naturalists who find no difficulty in mineralizing and consolidating similar materials every otherwhere, and in every situation in the Earth, be able to give any satisfactory reason why there are no

such appearances in this place? They cannot allege that there is not sufficient quantity of materials; nor that there is any defect in the quality of these. They must then be reduced to this argument alone, that there has not been sufficient time. But such an argument as this would be to reason without science; for how do they know that this is the reason? Is it from any other appearance besides this, that those materials have not been mineralized? In that case, to judge of the time from the state of things, and then to say, there had not been sufficient time, is plainly to give up the question, in begging that which should be proved. Had there been any mineralization begun, any consolidation taking place, it might perhaps have been supposed that to complete the work, much more time must be required. But when instead of that mineralizing operation having been begun, there is, on the contrary, a decomposing one everywhere visible upon the surface of the Earth, and in all the depth of this vast collection of loose materials, it would be no less than absurd to allege that nothing was here required

besides the continuance of time, in order to make land of those incoherent bodies.

Here is an important fact—no less than 600 feet deep of loose materials, through which water has penetrated long enough, so far as we may judge from the appearances of the country, where such ravines and such valleys have been formed out of those materials; yet no appearance of mineralization or accretion has taken place; on the contrary, the very solid granite is in a state of resolution or decay. Now we must be allowed to avail ourselves of this confirmation to the Theory, in which strata originally formed of loose materials, are supposed to have been consolidated by means of fusion, and not by any manner of aqueous solution.

But perhaps it may be alleged, that there are actually some appearances of this actual consolidating operation, as in certain parts there are to be perceived some calcareous stone upon the solid granite. The answer to this is plain. This is not the light in which our naturalist has viewed it. From his description it is clear, that here are only

the remains of greater masses; and that here, as well as every otherwhere upon the surface of the earth, solid bodies are dissolving and going into decay. It is from this well-vouched fact, that I have ventured to explain that enormous collection of travelled materials which appears in the Plain of Calabria, in a different manner from that of which the Chevalier de Dolomieu seems to have entertained the idea.

The Chevalier has informed us that there are marine objects mixed throughout all this mass of moved materials; and he seems to think, or he concludes, that those marine objects came immediately from the sea, while the materials, with which they are mixed or embedded, came from the dissolution of the rocks and solid land. I should think that there may be an opportunity of having this question absolutely decided by those who are on the spot.

If those marine objects are in their natural state, *i.e.*, as they come out of the sea; and if those kinds of objects, which are found in the solid strata mentioned as lying upon the

granite, are in a mineralized state, there would be good reason to suppose that the sea had contributed immediately to the formation of that collection of loose materials, which is amassed at the bottom or upon the flanks of those mountains. But if, on the other hand, there shall be perceived any similarity between the state in which those marine bodies are found in the solid strata and in the loose mass; or if in the travelled materials, there are any in a mineralized state, while there are some within the strata in which mineralization does not appear; in that case, we would be authorized to say, that there is no occasion to look for any other operation, by which the marine objects had been brought hither, besides that by which the gravel and sand had been here accumulated. Thus we again refer to natural history, or to the Chevalier de Dolomieu for the decision of that question.*

* [The Italian geologists who have subsequently investigated the geology of Calabria, have decided in favour of the marine origin of the great deposits of sand and gravel that cover the lower plains and creep up the sides of the mountains to a considerable elevation. In the

recent Geological Survey maps of that region a wide tract of quaternary marine sands and conglomerates is shown to extend between Cittanova and the sea coast, and to stretch in scattered patches northward by Mileto, and southwards along both sides of the Strait of Messina.

Hutton's unwillingness to admit that these deposits were laid down under the sea probably arose from the strong conviction he entertained as to the potency of sub-ærial waste and stream-action in the production and distribution of coarse detritus. But he might have granted that the sand and gravel were assorted under the sea, when the land stood many hundred feet lower than at present, while he still maintained the essentially terrestrial origin of the materials. The prodigious sub-ærial degradation which has taken place since the elevation of these marine quaternary sands and gravels is impressively shown by the manner in which they have been trenched by innumerable valleys, and their isolation in scattered outliers capping the ridges and hills. The torrents and rivers have laid down a newer series of fluviatile alluvia on the bottoms of the valleys that have been dug out of the marine terraces.]

CHAPTER IX.

*An examination of the Mineral History of the Island of Arran.**

IN the year 1786, when Mr. Clerk and I were at Glasgow on our journey to Galloway, we engaged Dr. Irvine to go with us the next summer to the island of Arran, where the doctor had been before, measuring the height of Goatfield.† He was to have been our conductor in taking a vessel down the Clyde and visiting several places by the way. Dr. Irvine died in the spring; the weather, to the month of August, was extremely unfavourable; and at that late period, it was not convenient for Mr. Clerk to undertake the journey. I proposed going alone, when Mr. John Clerk, junior,‡ was so kind as to offer to accompany me. We set out then

* [This chapter is referred to in vol. i, pp. 429, 467.]

† [Now always spelt Goatfell.]

‡ [Afterwards a celebrated advocate, Solicitor-General and Judge in Scotland.—L. H.]

directly for Arran by Saltcoats; and it is the lights acquired in this expedition, that I now propose to give in form of a mineral history.*

* [Had this chapter been published in Hutton's lifetime, it would have been the first general account of the geology of the island. Since his day many descriptions have appeared, of which the following are the more noteworthy:—

Outline of the Mineralogy of the Shetland Islands and of the Island of Arran. By Robert Jameson 8vo. 1798. Republished with additions and Plates in the same author's *Mineralogical Travels through the Hebrides, Orkney and Shetland Isles*, 4to, two vols., 1800.

View of the Mineralogy, Agriculture, Manufactures, and Fisheries of the Island of Arran. By James Headrick. 8vo. 1807.

A Description of the Western Islands of Scotland. By John Macculloch. 8vo. 1819. Vol. ii, p. 309.

The Geology of the Island of Arran, from Original Survey. By Andrew C. Ramsay. 8vo. 1841.

The Geology of Arran and the other Clyde Islands. By James Bryce. 8vo, first edit. 1855; fourth edit. much enlarged 1872.

Besides these general descriptions of Arran, numerous papers have been published in reference to special localities or formations, from the early memoir of Sedgwick

In setting out upon that expedition, I had but one object in view; this was the nature of the granite, and the connection of it with the contiguous strata. But upon examining the island, I have found it sufficiently interesting and comprehensive to make it the subject of a natural history, in describing the particular constitution of that small portion of the earth. The extremely alpine appearance of Arran from the continent of Scotland, even at the distance of the middle of the country, *i.e.*, from the Shott Hills,* had long been a subject of admiration to me; and it was there that I had always expected to have the nature of mountains, that is to say, the steps of nature in their origin and decay, better investigated than any otherwhere.

The discussion of the present question,

and Murchison (*Trans. Geol. Soc.* 1828, vol. iii, 2nd ser., p. 21), down to the present time. For the last few years the Geological Survey has been in progress there, and the southern half of the island has now been published, while the northern half is nearly completed.]

* [The hills in the parish of Shotts, Lanarkshire, are upwards of 50 miles in a straight line from the granite mountains of Arran.]

with regard to the subject of primitive mountains, may perhaps appear to have been too anxiously aimed at. But it is to be considered, that the present Theory must in a matter rest upon there being actually no such thing.* There is nothing positive in the character of a primitive mountain; it consists merely in this quality of not having been the effect of second causes. Consequently it would be unreasonable to demand a positive proof, as having been only the effect of the first cause. The being primitive is merely a supposition; it arises from no certain information, and it only expresses an acknowledgment of ignorance with regard to the natural history of those mountains. But from a person who affirms, that there is no primitive earth or mountain upon the surface of the globe, it is reasonable to demand that he should prove his proposition; and for this purpose nothing more can be required than that he shall show

* [That is, Hutton's theory involved a denial that primitive mountains form part of the architecture of the land.]

that those masses which had been held as primitive, have undergone some change in the natural course of things or operations proper to the globe.

It will, therefore, be sufficient for the present Theory, which admits of nothing primitive in the constitution of our land, if those pretended primitive mountains shall appear to have had a former state, different from that in which they are found at present; a state requiring no preternatural means, and a change accomplished in the natural course of things, and for the proper purpose of this world. Now I hope the examples I have already given with regard to granite will remove every doubt which might have been entertained on that subject, as I am persuaded that the actual examination of those places which I have indicated, must convince the most scrupulous enquirer who will give himself the trouble to observe them.

But perhaps it may be objected, that here is a generality founded upon a particular or two, and that the opinions of so many learned naturalists, with regard to these primitive masses, must not be overturned by that of

O 2



one who has seen so little of the globe.* This objection, however, will have no weight, when it is considered that the opinion of those naturalists had proceeded upon this principle alone, that they found an apparent nucleus in the globe, and concluded it to be primitive, for no other reason but because they did not understand the nature of that body, which they therefore

* [It was a favourite taunt of the followers of Werner that Hutton and his school were deficient in mineralogical knowledge and experience. It is interesting however to know that among his own countrymen Hutton's scientific reputation stood high. The reader may remember the amusing scene in the *Antiquary* between Sir Arthur Wardour and Jonathan Oldbuck where Scott makes allusion to "Dr. Hutton, the celebrated geologist," by putting his praises into the emphatic language of the Antiquary himself:—"Why old Dr. H——n told me, when I was in Edinburgh, that we should never find copper enough, judging from the specimens I showed him, to make a pair of sixpenny kneebuckles—and I cannot see that those samples on the table below differ much in quality."

"The learned doctor is not infallible, I presume?"

"No; but he is one of our first chemists; and this tramping philosopher of yours," &c., &c., *Antiquary*, Chap. xiii. See footnote *postea*, p. 257.]

supposed to have existed always, as it is at present. Such reasoning, or rather the reasoning upon such defective principles, will be exploded, if it is allowed that we have investigated the nature of this body granite, that supposed primitive nucleus of the earth, and have found that it had been forced to flow among strata, thus broken and elevated by that mass.

Now it will be no objection to this Theory, to allege that the instances are few in which those particular appearances are found, from whence the nature of those granite masses has been investigated. For so long as nature is acknowledged as being uniform, and as observing rule, the process of granite in the natural history of this globe, will be certainly established upon a single example, if that be unexceptionable, and if it be not invalidated by the opposite testimony of any other. If, on the contrary, anyone should allege that nature is not to be acknowledged as regular and steady, the question then would not be concerning the credit due to natural history which nobody disbelieves, but a sceptical opinion with regard to the truth of human

knowledge; and this is an objection which cannot be answered in a physical dissertation.

It may now be observed, that the present history with regard to the island of Arran, is not proposed as necessary in that question concerning primitive mountains, nor as adding any new light to the nature of granite, as already investigated; but as an example in Cosmogony, where it may be proper to see the connection of various things, or the several parts which enter the constitution of the globe, so far as we are able to examine.

I had long looked upon this island of Arran as a proper subject for the purpose of a mineral survey; and had therefore often intended to examine the particular construction of that island. It is now many years since Dr. Black and I set out upon a journey with that view; but I was then indisposed, and we went no farther than the west coast of Scotland. I have now accomplished that long projected undertaking this summer, 1787. And I have the satisfaction to find that my conjectures with regard to the interesting nature of Arran, were just. I knew

no farther than that there were most eminent alpine appearances in that island, as seen from a distance; that there was granite in those mountains; and that there were, besides, in the island, coal and limestone. But these, in an island of that extent, were sufficient to make it a proper subject of natural history, and interesting as leading to the knowledge of the original constitution of our land. The island of Britain is a country too great for that purpose, that of Arran, considering its extent, is not too little.

If in this little island of Arran, the form and disposition of the mineral bodies are such as to lead to the knowledge of all that is necessary in the production of the land, or surface of the earth, as a habitable world, in that case, the smallness of its extent will be a manifest advantage to the labour of a naturalist who examines it. For if the constitution of this body shall be reduced to a regular system; and if that system of composition may be applicable to all the rest of the earth, the smallness and simplicity of the part examined adapts it the more for the purpose of the undertaking; viz., either of

forming a theory to be applied to other parts unknown, or of trying the justness of a theory formed from the various appearances collected from the different parts of the earth. Let us, therefore, see how far the natural history of Arran shall be proper to try the Theory of the Earth which had been formed from that of other parts.

If a modern naturalist were to give the description of Arran, he would say, that it had for nucleus granite and schistus; and that, besides these, it was composed of secondary or tertiary concretions,* formed in a posterior space of time, and by means of operations which, were he to be ingenuous, he would confess he did not know. So far concerning the granite, schistus, and superincumbent strata; with regard, again, to the whinstone or basaltes found in this island, it

* [Or, as would now be said, formations. The terms Secondary and Tertiary were not used by Hutton in their definite modern sense as determined by palæontological evidence. He merely meant to denote by them a certain geological sequence in the history of a country, the rocks called secondary having been formed after the primary, and before the tertiary.]

would be said that there were many appearances of eruptive operations, which then would be considered as explaining those volcanic productions. I am to give a very different account of that island; but I would wish to give a simple view or description of its mineral history, without reference to any theory, that so it may be compared with every one, in order to see which is the theory that corresponds properly with such a history. For that purpose, I have been at some pains to study this island; and though I am far from having seen every particular in the mineral construction of this mass of land, yet I have seen enough to form a scientific history of the whole. I am also persuaded that in seeing every appearance possible, or that might be attained, in examining the island, I should only find a repetition of those examples of which I have seen many, or enough to determine in the most decisive manner, the chief questions in dispute among naturalists, and points most interesting with regard to the Theory of the Earth.

The island of Arran may be divided into

certain districts, which may be distinguished by the peculiar fossil* with which each of these abounds, in order to see the general structure of the country composed of those districts. For that purpose I shall first point out the geography of those different districts and the nature of the fossil by which they are characterised, so far as this is necessary; and then endeavour to give some idea of the shape in which those fossil bodies are found; as it is this form and connection of things, which, together with the nature of the substance, is to determine what operations had been employed for the production of that island, which is to be considered as a specimen of our earth.

The district with which I shall begin is a central district, reaching almost from the one side of the island to the other, but placed nearer to the north end of the island than the south. (See mineral plan.)† It is most

* [It is hardly necessary to remark that the word "fossil" was in Hutton's time used in its natural sense and applied to any rock or other mineral substance which could be dug out of the earth.]

† [The geological sketch map in Fig. 4 is generalised

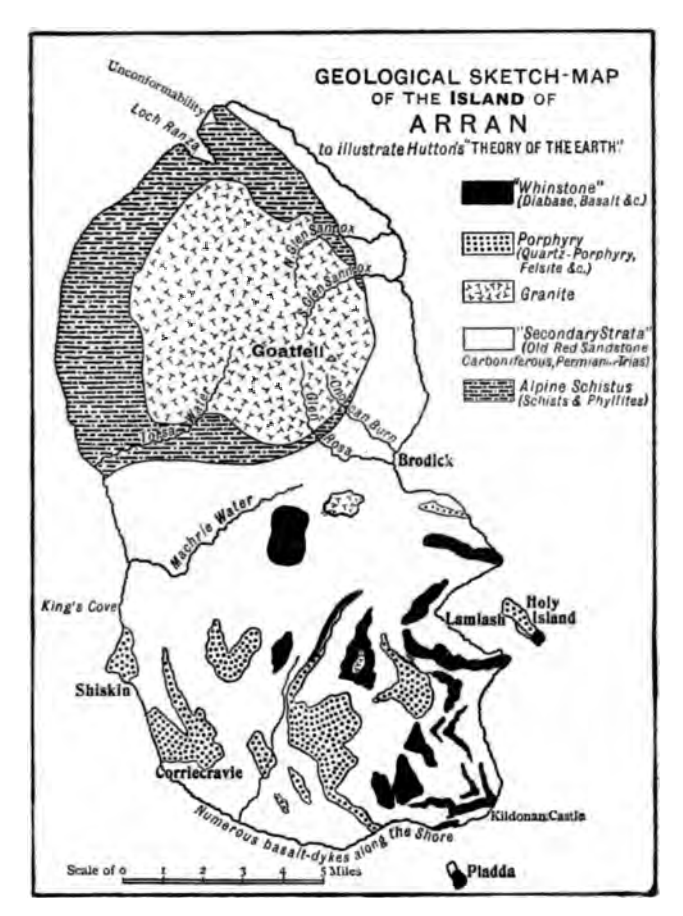


FIG. 4.—Geological sketch map of the island of Arran.

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and reduced from the latest work of the Geological Survey. For the sake of adapting it to Hutton's narrative only those groups of rock are represented which he describes. The Old Red Sandstone, Carboniferous and Permian or Triassic strata are thus all included in the unshaded part of the map.]

eminent in its appearance, and most distinct with regard to its matter ; this is the granite district, forming a mass of mountains of more than half a mile perpendicular height above the level of the sea,* and excavated on all sides with extremely deep valleys. All within this district is granite, except the accidents to which it may be subject, as will be afterwards explained.

The nature of this granite seems to be pretty uniform, or everywhere nearly the same.† The felt-spath is white, or little

* [Goatfell, the highest summit is 2,866 feet above the level of the sea.]

† [The well-known granite of Arran, in its two characteristic varieties of coarse and fine texture, differs from the older granites of the Scottish Highlands. The coarser variety reveals the presence of two kinds of felspar, quartz and black mica, the quartz being not infrequently in more less definite crystals enclosed in the felspar. The two minerals are also intergrown in what is called the granophyric or micropegmatitic structure. Numerous drusy cavities occur in which the orthoclase, felspar and smoky quartz show terminated prisms. It is interesting to notice how clearly some of these characteristic features of the Arran granite were appreciated by Hutton more than a hundred years ago. The rock, like that of the Mourne mountains in Ireland, is prob-

coloured; the quartz is transparent, and much approaching to the crystalline. There is but little appearance of schorl; and the mica is very dark and glassy, but in small quantity. What is most remarkable in this granite is the general disposition of its substance to crystallize, and to contain cavities in which not only the quartz-crystals are regularly formed, as in the cavities of all siliceous bodies, but also the felt-spath is crystallized, or assumes its proper shape, but without transparency; as also does the mica. So great is that disposition to crystallization, that one can hardly break a stone of this kind without perceiving some example of that operation, especially if viewed with the magnifying glass.

The quartz of this compound mass has more the transparency of crystal than the milky hue natural to that substance; and this crystalline-like substance, seems to have been assuming its own proper shape; so that this granite has somewhat the appearance of

ably connected with the great volcanic series of older Tertiary time, so well displayed in the West of Scotland and North of Ireland.]

a congeries of quartz-crystals embedded in a ground of felt-spath. This property of the quartz is directly contrary to that of granite in general, in which we commonly find the quartz impressed with the shape of the other bodies which had crystallized while yet the quartz was in a soft or fluid state. This at least is the case with the granite of Aberdeen, and also that near Portsoy described in Part I of this work.*

The second District to be now considered consists of alpine schistus, and is most immediately connected with the first. It lies mostly to the north of the first district; but it also surrounds the great body of granite with a skirt; so that this central mass is in a manner included within or surrounded by the schistus.

The nature of this body which is termed schistus though composed of various substances, is well known to naturalists; and there is nothing particular to be observed with regard to [its character in] this island, farther than that it is a hard slaty schistus

* [See vol. i, p. 104.]

with quartz in veins and masses.* We may therefore now proceed to what may be considered as the third district, although not so distinctly separated as those now described.

The two districts now divided are properly alpine, as being [formed of] the general substance which composes mountainous countries. In this island that great mass of alpine matter is surrounded by another district which comprehends the whole island. But that encompassing matter is extended very unequally around the alpine mass. At the north end, it is but a skirt around the schistus district and is confined, so far at least as I saw, almost to the shore. There is more of it, indeed, surrounding the alpine mass upon the coast as we come from the north end eastward; but still it is only a narrow strip; and upon the west side, where the schistus comes to the shore, it does not

* [The "schistus" of Arran forms part of the crystalline schists of the Southern Highlands of Scotland. It consists of metamorphosed rocks mainly of clastic origin, including pebbly grits and even bands of fine conglomerate. These rocks are usually inclined at high angles, and have a general strike towards north-east.]

consists, first, of sandstone, in general red, but some extremely white and beautiful, and apparently of the best quality for building; secondly, a species of pudding stone, or strata formed of gravel and sand; thirdly of marl, or red argillaceous, micaceous, and calcareous strata; fourthly of limestone, mostly in thin beds alternated with the former, and containing marine objects; and lastly of coal, of which there is a small quantity or little field upon the extreme point at the north end, consisting of two or three workable edge-seams, as they are called, or vertical strata of blind coal—that species which burns without flame or smoke.

This mass of strata, in general around the island, is horizontal, or not greatly changed from its natural position, except where it comes to be in connection with the alpine bodies, or otherwise affected by the bodies which remain now to be considered.

We have thus given a description of that mass which I consider as the ground plan or general limiting body of the island; and now we are to consider the island as composed of a north and a south half. The north half

we have already described; and now we are to proceed in endeavouring to give some idea of the other.

As we have distinguished two different mineral districts in the north half of the island, we are now to do the same with regard to the south; but it must be observed that the distribution of those distinguishable masses in the south half is by far too intricate to be delineated in any plan, and can only be understood in being described upon general principles, and illustrated by particular sections. This then it will be our business to undertake, after giving some general view of those two districts and their peculiar fossils.

The fourth division is what I call the porphyry district, in order to distinguish it from the others; and to generalize the different bodies of which it consists, as having a proper affinity with each other, and also with this term porphyry, which with great propriety may be applied to some of them.* I shall now give a more particular description

* [In the southern half of the island innumerable sills and dykes of various acid rocks pierce the newer red sandstone and Carboniferous strata. Some of these are

of them, so far as regards their general place and character as mineral bodies, without examining their particular shape and situation in the strata with which they are found connected.

The porphyry district comes next in succession as we proceed from north to south, and it reaches from the one side of the island to the other. It is within this district upon the west coast, that I found a mountain of porphyry, which in that place was two or three miles wide. This porphyry

fine-grained felsites, others are characteristic quartz-porphyries. The granite nucleus is also traversed by abundant veins of fine-grained felsitic material. There seems every reason to believe that these various acid protrusions should be classed with the granite as parts of the Tertiary volcanic phenomena. No continuous mass of felsite or quartz-porphyry crosses the island as Hutton may have surmised. His account of the intricacy of the structure of the southern half of the island has been amply confirmed by subsequent observers. Hitherto no map has attempted more than a mere generalised representation of the geology. In recent years, however, the ground has been mapped in detail on the Ordnance sheets (6 inches to a mile) for the Geological Survey by Mr. W. Gunn, and the complexity of the structure can now be more fully realized.]

runs into the sea without any appearance of the strata upon the shore ; and in so far this place differs from the rest of the island, where the strata are always found upon the shore ; except upon the north-west, where the schistus comes to the sea. This mountain, though far from the height of the granite mountains, seems to be a great ridge that runs from the sea side at the north of Carcraven,* to the eastward through the middle of the island, but how far I do not know.

This mass upon the west coast may with great propriety be termed a granite, as to its general or external appearance, forming a mountain of one mass, and breaking or separating into great blocks precisely like the granite, that is, giving appearances of stratification in certain views. But this mass by its internal structure is more properly a porphyry, as it has a general ground, and as this ground is maculated with the crystalline or transparent quartz and the felt-spath. I would therefore term it a granite-porphyry, as containing almost the same materials as granite, only in a porphyry form.

* [Corriecravie, near Sliddery.]

This is the description of one particular mass; but the general ground of all the porphyry bodies contained in this district, I think, is what may be called petuntze, or porcelaine stone. It is an intimate mixture of the felt-spath and siliceous substance, and perhaps some others, so as to be uniform in its structure, with little or no appearance of the sparry state, as in granite. This ground is to be found variously tinged, sometimes greenish, sometimes reddish, and sometimes very white; in which last case it is the proper petuntze or good porcelaine stone. But this petuntze ground is to be found variously maculated, and then it becomes a porphyry, in containing either the quartz or felt-spath or both in their distinguishable state.

I have described the granite-porphyry upon the west coast, and now it may be observed, there is on the east coast, in the island of Lamlass or the Holy Island, which forms that fine harbour, a proper petuntze, as being but little maculated in general, although upon a strict examination, there are to be found also the transparent quartz and

fragments of felt-spar, sufficient to denominate it by the general term of porphyry. Between these two extreme places, where the porphyry is found so distinctly in the rocks upon the coast, I have reason to believe that this body pervades the island more or less; although in the middle, all being covered with soil, moss or vegetation, there is not that opportunity for a naturalist who takes a cursory view of things, to observe, as on the coast where the rocks are laid bare. But in tracing the rivers or rivulets, I have found the petuntze on both sides of the island; and I have every reason to believe that it prevails throughout this district. I found it on my road across the island from Torylin to Lamlass, in a stratum above the red sandstone; and I have it marked in my pocket-book that the heights then seemed to be of porphyry-granite.

Under the general term porphyry, I might have included another body, now to be examined, which in like manner pervades all the island south of this fourth district. But I think it is more distinct to name this body

whinstone,* which it most properly is, and to show the affinity that may be observed between this whinstone and the porphyry now described.

The ground of the porphyry is a petuntze, which consolidates in the fire to porcelain, instead of melting to a glass; whereas the ground of the whinstone is very vitrescible in consequence of a ferruginous mixture.† But so far as the whinstone in many places of this island contains the same crystalline and felt-spath bodies, it may be properly

* [Besides the felsites and quartz-porphyries, the southern half of Arran includes a large number of sills or intrusive sheets of different dark basic igneous rocks which are here grouped by Hutton under the general name of "whinstone." They have been intruded into the newer red sandstones, and obviously form part of the general Tertiary igneous series of the island. Probably most of them are, on the whole, older than the acid protrusions. They include varieties of dolerite and gabbro.]

† [It is interesting to observe that Hutton discriminated rocks by testing their respective fusibilities and comparing the results of their fusion. In this respect he followed the example set by the illustrious de Saussure (see *Voyages dans les Alpes*, vol. i, pp. 122–127).]

termed a whinstone-porphyry, of which we have great varieties in Scotland. It is therefore in distinguishing the grounds of the porphyries contained in the fourth and fifth districts that we have formed a division in the order of our history, and not from the constitution of those two different rocks which might be both properly included under the general term of porphyry. I have further to remark that the whinstone in this island is sometimes maculated with felt-spath, and that peculiar quartz which is characteristic of the Arran granite. This observation also takes place with regard to the porphyry of the fourth district, but there it is less to be wondered at, as that porphyry is more contiguous with regard to the alpine granite than is this whinstone, which occupies the most southern part of the island, some of which is far remote from the granite mass.

Having thus described the different bodies of which the island of Arran is composed, and placed them in the different quarters where they may be found, we may now proceed to examine the particular shape and connection of those bodies; that so we may

have data to reason with regard to the order and priority in the formation of those bodies; as well as to find grounds for judging with regard to the means employed by nature in producing this particular island, or land in general thus composed.

Our head-quarters were at Brodowick,* and our first object was to examine around the mountain of Goatfield for the connection of the granite with the strata or surrounding bodies. This however cost us a great deal of trouble to accomplish. After being disappointed in our searches upon the mountain where we had flattering appearances, and where we found what we wanted in a loose block of granite upon the surface, we went up Glen Rosa which is to the west of the mountain, a valley terminating in an impassable mountain, at least in appearance; a glen which is at least half a mile perpendicular deep, in measuring from the tops of the mountains on each side; and a glen the most barren for every purpose, perhaps, but that

* [Now written Brodick. The word means "broad bay," and is one of the relics of the Norse occupation of Arran.]

of studying nature; for in this dreary glen is to be found a charming picture of nature in decay, or of lofty mountains going into ruin, apparently without a purpose.*

In proceeding from the sea side where the red sandstone is found inclined but little, we traced strata more inclined till they came to the schistus, with which they seemed to be united or contiguous in a situation nearly approaching to the vertical. Not long after this, in entering between the two mountains† we came to the solid granite; but betwixt this and the schistus there is, in this river and its banks, a space of a few yards only, in which the rock had disappeared. Here, therefore, we were dis-

* [The granite of Arran everywhere decays into sand, which gathers below the crags and around the blocks and boulders, until swept down by rain into the watercourses. Each mountain side and glen furnishes impressive lessons in the progress of rock-weathering. Hutton's picture of the wildness of Glen Rosa would be more appropriately applied to Glen Sannox, the valley to the north of Goatfell.]

† [That is between Goatfell and its spurs, forming the east and north sides of Glen Rosa, and the high ridge forming the west and south sides.]

appointed; although, at the same time, we had every reason to suppose that the junction of the granite with the schistus was here made in the vertical situation, the strata being superincumbent upon or leaning to the granite.*

We next traced up from the shore the river of South Sanox, which is to the east of the same mountains, and has but a short course to the sea. Here we found the same appearances as on the west; and here we were equally disappointed in missing the immediate junction of the granite and schistus, the object of our pursuit, only by the space of a few yards or feet.

After making some other fruitless attempts, I set out on horseback for Loch Ranza; with a view to investigate the same object by the way, as well as to examine the north end of the island, where I knew the coal and slate were worked near the shore. Upon this road I observed that the North Sanox river, which I had crossed in entering

* [The actual contact of the two rocks is still obscured here by detritus, and a similarly concealed junction occurs in South Glen Sannox.]

the schistus district to the north, runs nearly in the junction of the schistus and the granite mountains, the characters of which are very distinguishable to the view. I then went forward, but in returning I quitted my horse, and went over the mosses and muir towards the heads of that North

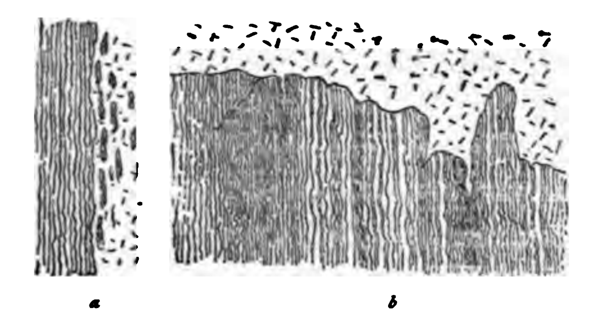


FIG. 5.—Sections in the North Sannox Water, Arran, showing junction of the granite with the schists.

Sanox river which there divides into two streams. Here I had the satisfaction to find the immediate junction of the schistus with the granite, in the solid rock, exposed perfectly to view, and that in both of these rivulets, a little way above their junction.*

* [In the sections in these two streams the intrusive nature of the granite is clearly observable. The accompanying figures represent different parts of the junction

Nothing can be more evident than that here the schistus had been broken and invaded by the granite; as in this place the regular stratification of the vertical schistus is broken obliquely by the other rock, and parts of the schistus involved or almost insulated in the mass of granite, which from this junction enters and traverses the body of the schistus in little veins terminating in capillaries. I had seen many specimens of this in the loose stones in different quarters, some of which I have brought to Edinburgh; but in order to homologate these examples with the cardinal

line between the schists and granite in the north fork of the Sannox Water. In one instance (Fig. 5*a*) the granite has been intruded along the bedding, and has caught up and enclosed numerous pieces of the schists. In another part of the contact (Fig. 5*b*) further down the stream, the line between the two rocks crosses the watercourse, and the granite has broken across the schists, the junction being notched and wavy, while, as Hutton observed, small veins of the igneous rock may be traced outward from the main body, crossing the quartz-veins by which the schists are traversed. The intrusion of this granite obviously took place long subsequent to the metamorphism of the schists.]

fact, the junction of the schistus and the granite mountains, it was necessary that I should have the actual observation with regard to a thing of which I could not entertain a doubt.

Not contented with this view of those two alpine bodies, in that jaunt which I had taken alone, I wished to give Mr. Clerk the same satisfaction, and also, to see this example upon the summit of a hill as well as in the bottom of a valley. A good opportunity here occurred to make the trial; for to the south of Goatfield there rises a shoulder, which may be considered either as the summit of a hill or the basis of that mountain; it is called Glen Shant hill. Now from the junction of the schistus and granite which we had traced in Glen Rosa, and that which we had in like manner observed in the head of the cataract or Glen Shant,* we knew that the line of

* [By the Cataract, Hutton obviously means the waterfall over the face of the schist a little below the old mill-dam, or what is now known as the Cnocan Burn. The actual junction of the granite and schist is there concealed by detritus, but the veins of granite

junction, which we were in quest of, must run over the top of this shoulder or moun-

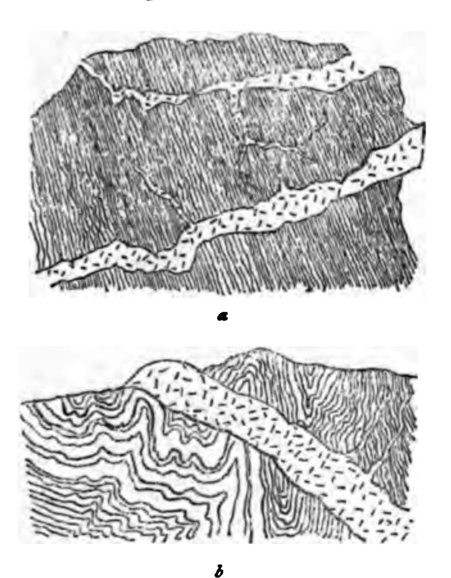


FIG. 6.—Sections in Cnocan Burn, below the Mill-dam, showing veins of granite traversing schist.

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sketched by Mr. Clerk are still to be seen. Some of these veins are shown in the drawings (Fig. 6*a* and *b*) recently made for this volume. A fact is here noticeable, of special importance in regard not only to the intrusive character but the late date of the granite. One of the basic dykes which, by a process of cumulative proof, have been assigned to the Tertiary volcanic period, is seen immediately below the mill-dam to be traversed by narrow veins of granite, and has undergone considerable metamorphism by the large body of granite

tain. One day, therefore, when disappointed in seeking this junction on the Cataract rock, which with the fair weather had become almost dry; and when Mr. Clerk had taken some drawings of several veins of granite, which traverse the schistus rock from the junction which is here no more but just out of sight, we directed our course to the summit of this hill, from whence we could look down upon the place of junction in Glen Rosa. Here we had little trouble in procuring what we wanted; and found the most satisfactory evidence of the point we sought to ascertain.

For though, by reason of the covering of moss and vegetation, we had but a very interrupted view of this object, the immediate junction of the granite and schistus, which here appears in many places upon the summits of bare rock standing up among the heath and moss, yet we had every other reason to be perfectly satisfied with

immediately behind it. Thus the intrusion of the granite has obviously taken place subsequent, not only to the plication and metamorphism of the schists, but also to the uprise of some of the basic dykes.]

what we saw; and having once got hold of the clew, or catched the scent, we traced back with more animation than could have been expected from such an innocent chace, the object of our investigation, all the way to the very place from whence we had set out at the head of the Cataract rock. It was here we had an opportunity of observing a most distinct trait in the natural history of that mineral appearance; it is that of the granite breaking the schistus in large steps. The line of junction here runs a little space parallel with the stratification of the vertical schistus, and then at right angles with that direction, or across the stratification, so that the junction is evidently in great steps.*

Both upon the summit of this hill and on the top of the Cataract rock in time of drought, may be seen great veins of granite traversing the schistus, and ramifying in all

* [The line of boundary between the two rocks is somewhat zigzag, or notched, the granite projecting in occasional prominences into the schist, so that the contact is sometimes parallel with the foliation and sometimes cuts across it as in the junctions shown in Fig. 5.]

directions. It was here that I procured a specimen of this, which I have had conveyed to Edinburgh, though weighing above 600 pounds.*

Thus we have ascertained the shape of the granite, and its particular mode of junction with the schistus which surrounds it. The granite is one continued mass, forming mountains composed of peaked tops and intermediate ridges; and is variously hollowed out into higher and lower valleys, in which the water falling on the declivities is gathered. In immediate conjunction with that mass of granite, is the schistus forming hills or mountains of an inferior order, and occupying all the island north of the granite, almost to the shore, where sandstone and pudding-stone strata are found, as has been already observed.

Let us now employ those data in forming some general conclusion which may be applied in Cosmology.

It appears from this view of the granite, that it is a mass formed posterior to the alpine schistus, so far as the changing of

* [This specimen is not now known to exist.]

place and shape may be considered as formation; and that, therefore, this great body of granite had been actually in a state of fusion by means of subterraneous heat. Here is a matter of fact, or physical truth, which I hope will be found to have been concluded upon just grounds, and may then be employed in examining the various theories of the Earth.

In these mountains, where there is so much bare rock exposed to view, and where this rock is continually going into decay by the operations of the sun and atmosphere, I had a good opportunity of observing also a fact with regard to the question treated of in the Chapter concerning the stratification of granite [see Chapter VI]. For though to look at those decaying mountains, and observe the regular shaped blocks that are just loosened and ready to depart in hurling from their craggy sides, one is apt at first sight to conclude that those rocks must have been originally stratified in the manner of sandstone, this is only a premature judgement. It is one which I certainly made before I knew what I was looking at; for in

approaching the mountain of Goatfield, I took the south-west promontory or shoulder of this mountain for one composed of schistus, in judging at a distance from the shape of its fragments or manner of breaking; and I was much disappointed in not finding here the junction of the granite and schistus, as I had expected from the different aspect of those two contiguous parts of that mountain. In examining more closely into the matter, it is, I think, sufficiently evident that this regular decay or apparent stratification of those masses of granite is only occasioned by the regular contraction or basaltic cracking of the mass in cooling; and it is the influence of the atmosphere which, insinuating itself into those invisible cracks, is the cause of that apparent stratification, an appearance which in certain views is very imposing.*

* [The spur which runs southward from the summit of Goatfell presents a deceptive appearance of stratification. The rock seems from a distance to consist of beds which dip steeply down into the valley on the east side. This pseudo-stratification, so common among massive eruptive rocks, is specially well developed in



Fig. 7.—Jointed structure of granite, Goatfell, Arran.

the granite of Arran, where every crag and mountain declivity displays it more or less characteristically. The geologist will find excellent examples of it on the shoulders and immediately below the summit of Goatfell (Fig. 7). It is interesting to notice how accurately Hutton inferred the origin of this structure.]

Fig. is a drawing taken exactly from a part of the rock on the summit of Goatfield.* By this it will appear that the cracks by which the rock is finally to be separated into regular blocks, are not as yet complete; that they had been begun originally in the cooling or contractions of the mass, and that they will be perfected in time by the influences of the sun and atmosphere.

Thus we have discussed the subject of granite, in finding every confirmation to our Theory that perhaps the nature of the subject will admit of. We should now proceed to examine the form or cosmological character of the porphyry bodies; but first something may be said with regard to the connection of the schistus, and the sandstone strata which surround it.

The immediate connection of the alpine schistus with the strata of the low country is an object which I have long looked for, I may almost say in vain. I expected to have

* [Fig. 7 is a reproduction of a photograph taken immediately below the south side of the summit of Goatfell, to replace the lost drawing referred to in the text.]

seen it in entering the Grampian mountains, both by the Ammon* and the Tay, but I was disappointed in my expectations. I doubt not but that it may be found, but I had not sufficient opportunity to investigate the subject, or was not fortunate enough to find it in either of those two places.† I have in like manner looked for it in both sides of the southern mountains of Scotland, and that in several places, without receiving any satisfaction upon that subject.‡ In the island of

* [Now written Almond.]

† [Hutton missed the junction between the Highland schists and the overlying Lower Old Red Sandstone, because for the most part of its course it is concealed by a powerful fault, and overspread with superficial detritus. In some places, where bay-like expansions of the younger formation lie on the north side of the fault, excellent exposures of the unconformable junction are to be seen. One of the best of these sections occurs in Glen Turret, near Crieff.]

‡ [The author did not make until the following year (1788) the memorable excursion to Siccar Point, so eloquently described by Playfair in his biographical notice of Hutton, where the red sandstones and conglomerates rest on the upturned edges of the Silurian strata that form the Southern Uplands of Scotland. See vol. i, p. 454 *et seq.*]

Arran I have sought it carefully without finding it, in a place where I thought it was certainly to be found; and I found it, in a place where I had not thought almost of looking for it.

The coast around Brodowick Bay is sandstone, and the Cataract Burn or Glen Shant Water [Cnocan Burn], already mentioned, runs into the bottom of that bay. The solid rock is seen almost all the way up this brook to the high cataract which falls over the schistus immediately connected with the granite of Goatfield. Nothing therefore could appear more promising than this situation of things for discovering the connection of the schistus with the strata here enquired after; yet, though I have carefully examined the course of this burn, I am still left in the dark with regard to the point in question.* I shall now give a short history of what I could learn in that place where I

* [The part of the stream where the sandstones and the schists come together is obscured with boulder-clay, but even had the rocks been visible their relations to each other would have been found to be obscured by a fault or by an intrusion of felsite.]

was disappointed, as well as in that where I had the only satisfaction I ever received with regard to this subject.

I did not see the sandstone of the coast in the brook at the bottom of this hill; but I found much red indurated micaceous marl, sand and gravel-stone, which I at first supposed to be the same with that upon the coast. But these indurated and consolidated strata which are much inclined, are so different from the sandstone of the coast, and at the same time so similar to many of the vertical strata of the schisti in the southern schistus mountains of Scotland, that were they traversed with quartz, as is commonly the alpine schistus of this island, I should not scruple to include them among the schistus, as having had the same origin and accidents. So far from this, however, is the case, that I found them traversed only with calcareous veins.*

* [As a further instance of Hutton's quickness and accuracy of observation, it should be remarked that he here clearly distinguishes between the red (Permian or Triassic) sandstones of the coast and the red Carboni-

Before we arrived at the alpine schistus which forms the cataract, we found a great bed or body of most solid blueish white siliceous stone, which I at first supposed to have been a petrosilex, which it may be in the estimation of some naturalists; but now upon trial, finding it more fusible than flint, I am inclined to consider it as a species of petuntze. This body appears to be of very considerable thickness; I did not see its shape distinctly, but supposed it to be erected against the mountain like the rest, as it is immediately contiguous with the schistus of the cataract rock.* But below I could not discover the immediate connection of this siliceous or petuntze rock with the softer strata, which being less durable have been worn away.

I shall make no comment upon this history of those natural appearances, but proceed to give an account of what I saw at the other extremity of the alpine schistus.

ferous and Old Red Sandstones between the coast and the mountains.]

* [This is another of the numerous felsitic intrusions of the island.]

Loch Ranza at the north end of the island, is properly within the alpine schistus; but, in tracing the shore, upon the east side of the loch or bay, we come to the extremity of this schistus district. Here the first thing that occurs is the immediate junction of the inclined strata of schistus and the other strata which here appear to be a composition of sandstone and limestone; these strata are equally inclined with the schistus, but in the opposite direction. Those two different kinds of stratified

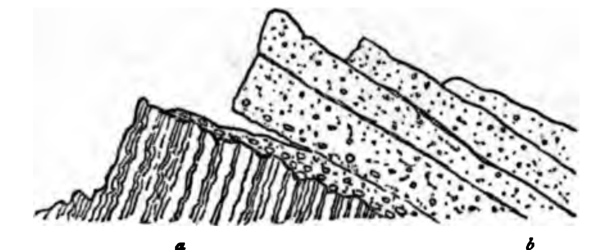


FIG. 8.—Section of unconformable superposition of Upper Old Red Sandstone *b* upon schists *a*, Shore, east of Loch Ranza, Arran.

bodies rise to meet each other; they are somewhat confused at the immediate junction; but some of the sandstone or calcareous strata overlap the ends of the alpine schistus. The drawing which I took in my memo-

randum book upon the spot, is seen in Fig. . This is upon the sea shore, and, I believe, within the sea-mark.*

This, I think, is the only immediate junction, that I have seen, of the alpine schistus and what are commonly reckoned the strata of the Globe, and acknowledged upon all hands to have been formed of matter deposited in the bottom of the sea. Here they are both equally inclined, nearly at 45°; and were it not for the little overlapping of the strata upon the schistus, it

* [As this was the first unconformability which rewarded the long-continued search of the author, it acquires a special interest for geologists. In a recent visit to the locality the Editor made the accompanying sketch (Fig. 8) to replace the lost drawing referred to in the text. The schists dip E.S.E., at angles ranging from 40° to 60° and higher. The breccias, cornstones and sandstones (? Upper Old Red Sandstone) are inclined towards N.N.W. and W.N.W., at from 20° to 30,° and may be seen wrapping round the denuded ends of the older strata. It is as perfect an unconformability as could be desired. Hutton makes no mention here of the further evidence of a complete break between the two formations supplied by the fragments of schist contained in the breccias.]

would have been impossible to have said which of these two bodies of strata or stratified masses, was superincumbent on the other. I had little time to examine this coast, as I would have inclined, otherwise I should perhaps have made other interesting observations of the same sort. But now it is time to return to the porphyry district.

If the porphyry hill upon the west coast of Arran shall be considered as an insulated mass of granite, which is perhaps a proper view of things, in that case, we must refer the explanation of this body with regard to its form, to what has been said upon the head of granite; for I have no observation with regard to the junction of this great mass and the neighbouring strata. If, again, it shall be considered as connected with the petuntze-porphyry in its origin, as it is both in its place and the nature of its substance, it will be properly explained by what is now to be given upon that head.

Though I did not see the immediate connection of the granite-porphyry with the strata, this is not the case with the petuntze-

porphyry. I have the most convincing and unquestionable proof that, on both sides of the island of Arran, this last body has been made to break and invade the strata of sandstone and marl, in every conceivable manner, that is, both perpendicularly and horizontally in every degree. The examples of this that I saw, are particularly to be found upon the coast at the Shiskin, and up the Clachan burn beneath the limestone quarry hill; on the east side again, in the Holy Island, and on the coast at the south side of Brodowick Bay, as also in a steep burn upon the north side of Glen Shirrah.*

One example of this upon the Holy Island is so evident and observable, that I

* [Hutton observed that the felsitic intrusions took the form of dykes and sills, with endless intermediate varieties, and this passage shows that he had devoted a good deal of time and labour in traversing the island for the purpose of verifying and checking his theoretical conclusions. The localities he here cites supply good illustrations of the doctrines for which he contended. The instances of the Holy Island and the south side of Brodick Bay are more particularly described in the text. The burn on the north side of Glen Shirrah, here referred to, is the Allt an Bhrighide.]

had perceived it at the distance of a mile or two at sea, in approaching the island of Arran from Saltcoats. I then pointed it out to Mr. Clerk as an example of whinstone invading the strata. I was then deceived as to the matter of the mountain or the invading substance, and we were not a little confounded afterwards, at finding this great pyramidical mass of rock which so beautifully forms the harbour of Lamlass, to be almost entirely composed of petuntze-stone. Nevertheless the example of invasion was visible, and we were far from meeting with any disappointment upon that head. It is the fracture of the horizontal strata, about the middle of the island upon the east side; the strata are here broke off and removed entirely on the north, in place of which comes the petuntze-rock, which also involves the strata in forming the mountain atop of them. The horizontal strata below are continued to the southward; but towards the south end of the island, in continuing upon the same shore, we came to a great vein or dyke of the same petuntze-porphyry rock; this breaks and traverses perpen-

dicularly the strata which are here to be seen on both sides of the dyke.*

An example of the same kind with this last is to be found at the south side of Brodowick Bay, upon the shore. Nothing can be more satisfactory than these examples; for in those two cases, we have both the horizontal and perpendicular section of the object; the one upon the flat shore under the cliff, and the other upon the high cliff

* [The felsitic protrusion of Holy Island has broken through and overflowed the red (Permian ?) sandstones. The strata are truncated by a kind of vertical wall of the igneous rock some 200 feet in height as shown in Fig. 9.

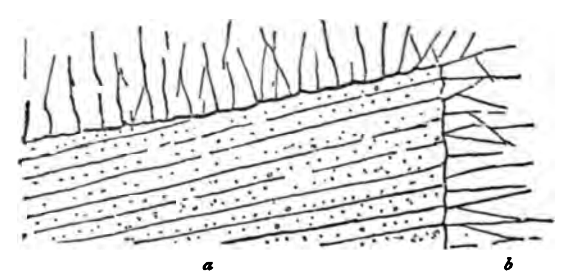


FIG. 9.—Junction of Felsite *b* and Sandstone *a*. East side of Holy Island, Lamlash.

Further south, as mentioned above, a broad dyke of similar material may be seen cutting the sandstones and some doleritic sills, and also severing one of the basic dykes.]

over the shore.* These two examples are also remarkable in this; that the great petuntze dyke is accompanied with smaller



Fig. 10.—Compound dyke of Felsite (petuntze) and Basalt (whinstone), Shore, Corriegills, Arran. (*a.* Red Sandstone and conglomerate; *b.* Basalt; *c.* Felsite.)

ones of whinstone which gives a complexity in the example not a little puzzling to the observer, but extremely instructive in the science of Cosmology [Fig. 10]. This last

* [There are several felsitic intrusions along the shore between Brodick and Corriegills. That to which Hutton appears to refer consists of two rocks, a felsite and a basalt, which have both been intruded between the bedding-planes of the sandstones and conglomerates. Each of them has chilled edges, and it is difficult to say which is the older of the two. The acid rock has a well-marked flow-structure, crumpled in places. It has been more irregularly injected than the basic rock which was not improbably the first intrusion. A thin irregular layer of conglomerate adhering to the basalt is interposed between the two sills (Fig. 10).]

observation with regard to the whinstone, is perhaps out of its place; but as the combination of those two different bodies, here breaking and traversing the strata, are so distinct objects, and so worthy of the attention of a naturalist who would study them, I could not help pointing out these particular examples, although there is such a general exhibition of the same nature throughout the whole island of Arran.

I need only say further upon the subject here examined, that I have found this petuntze-porphyry in every shape or situation in relation to the strata; I have found it at top, forming a stratum above them; I have found it below, doing the same under them; and I have found it breaking and involving them almost in every manner of way. The drawings are best calculated to give a proper representation of this subject; but the proper execution of that scheme would have taken more time and pains than we had to bestow.*

* [It is greatly to be regretted that the drawings made by Clerk to accompany this part of Hutton's MS. should have disappeared. But the chief points which they

From the form or diffusion of these porphyry bodies among the regular strata, we may observe that this petuntze substance is at bottom no other than a species of basaltes, considered as a subterraneous lava; and that it differs from the common species in wanting that ferruginous matter in its composition which characterizes the common sort of whinstone of this country. This observation is also sufficiently confirmed in the basaltic appearance of those porphyries of Arran, both upon the east coast and the west, where those rocks appear in the columnar shape, or assume the resemblance of vertical strata, and break into equilateral or rhomboidal blocks.*

The description which we have now given of the bodies contained in the porphyry district has made the particular examination of the southern district of the island almost superfluous or an easy matter. For having

would have illustrated are probably shown in the figures here given.]

* [The porphyry mass at Drummadoon on the west side of the island is a picturesque example of columnar structure.]

shown the affinity of the porphyry with the whinstone which characterizes the southern district, and having observed that the porphyry is found to have broken and invaded the strata in every supposable manner, we have only to substitute the one species of body for the other, and then the description will equally apply to both.

But in applying that general description of an invading body to the whinstone district of the island, this may be restricted to that particular mode of pervading the strata which appears in the whinstone separating the different beds of sandstone and marl, without including the other mode distinguished by the same species of body breaking the continuities of those stratified masses. Here, therefore, it is only meant to make a distinct division or district of the whinstone as invading the strata in one particular way, which is that of forming interjected beds and great irregular masses among the natural strata of marl and sandstone, reserving the other regular shape of this invading body to be examined afterwards, when it is to be considered as general to the

whole island, and not peculiar to any district exclusively of the others.*

Having thus gone through the several districts into which, for distinction's sake, we have considered the island of Arran as divided, it may now be observed that it is not hereby meant to maintain that these districts are in nature absolutely distinct without any interference with each other; on the contrary, the porphyry and whinstone districts which are contiguous, are also in some measure mixed together. For as the petuntze-porphyry may be found in the whinstone district in some degree, so in the porphyry district, between Lamlass and Brodowick Bay, there is abundance of those beds or masses of whinstone interjected among the strata. Nevertheless, there are actually such distinguished districts where those two different species of invading bodies may be found respectively more general or in greater abundance.

* [That is to say, the sills or intrusive sheets which are specially developed in the south part of Arran are here taken by themselves, and the dykes, which occur throughout the whole island, are left for treatment further on.]

We may now consider the island of Arran as one whole without any distinction of districts; in order to describe the peculiarities which this island possesses, not exclusively with regard to the rest of the earth, but most eminently, being here more remarkable than in most other places, perhaps more than in any other.

From the many whinstone dykes or veins which traverse the strata upon the shore of the shire of Ayr, I had reason to expect something of the same kind in the island of Arran. But the number and complexity of those dykes, which we found upon all the shores of that island, surpassed anything which I had imagined, or could well suppose, from what I had ever seen before; for in walking along the shore in every part of the island they occur so frequently and with such variety, that it is a thing endless to endeavour to describe particulars.* We first began to

* [The extraordinary number and variety of the basalt-dykes in Arran, which struck Hutton, has impressed every subsequent observer, and has been often described. In particular, L. A. Necker de Saussure, in 1840, gave an account of them (*Trans. Roy. Soc. Edin.*, vol. xiv, p. 667).

delineate these appearances, in taking the order, shape and size of those dykes as they occurred in proceeding along the shore; but we soon had recourse to a generalization of those facts; in perceiving that they are everywhere found; that they are of various sizes, from a foot or two of thickness to forty or fifty, but generally under ten or twenty; that they are not confined to any particular direction, but run every different way; and that they not only intersect each other occasionally, but even in some parts of the coast, as for example, the south side of Lamlass Bay, they give a reticulated figure to the horizontal section of the ground, which is to be seen when the sea has ebbed.

It must not be thought that this subterraneous operation of whinstone invading the strata from below had been confined to the shore, where the beds are generally more

For the first time they have been mapped in detail by the Geological Survey, but it has not been possible to find room for all of them on the one-inch scale map. The reticulated ground-plan of intersecting dykes is specially displayed at low-water in Whiting Bay and along the southern coast of the island.]

flat; those dykes or perpendicular veins of whinstone are universal to the island, breaking and traversing every mass, the granite itself not excepted. It is true, indeed, that this accident, as it may be called, seems to occur less frequently in the granite masses than in the strata upon the coast or the schistus on the north end of the island. We found it, however, most unequivocally in those granite mountains; and not only is the granite "dyked," to use the miner's term, by whinstone, it is also traversed in like manner by petuntze. For upon the north shoulder of Goatfield, a little below the summit of that mountain, which here is but a thin partition dividing Glen Rosa on the west, from that of the Cory [Corrie] on the east, the mass of granite is here traversed perpendicularly by a dyke which is more properly petuntze than whinstone. Our curiosity in examining this dyke, tempted us to slip down this place, in descending the mountain into the high Cory Glen, an idea which could not have entered the head of any sober person who was not a mineralist.*

* [A vast number of veins of finer-grained acid

There is also in Glen Rosa on the other side of the mountain a dyke of perfect whinstone, twelve or fourteen feet wide, traversing the solid granite, in the course of the river and running in a contrary direction to that of the petuntze.* This is enough to prove the universality of the rule with regard to the island; for, as to all the other districts, that occurrence of dykes is too general or common to require any particular indication.

I would only here further remark that it would appear, from observations at the south end of the island, that these perpendicular dykes, which traverse the strata, had been the latest occurrence in those mineral operations; for the horizontal beds of whinstone which are there alternated with the sand-

material traverse the granite of Arran. These intrusions, though later than the uprise of the main body of granite, probably belong to the later phases of the same extravasation of granitic or granophyric rock.]

* [This is one of the most conspicuous and continuous dykes in the island. It runs for some miles in a N.N.W. direction in the granite, which, in some places, forms vertical walls on either side of it, the material of the dyke having decayed so as to leave a chasm representing the original fissure.]

stone and marl, are evidently traversed by the perpendicular dykes.*

There only now remains one peculiarity to be described, as proper to this island of Arran, so far as I know, or to volcanic eruptions. This is a substance which has every appearance of glass.† It is generally

* [Not the least remarkable proof of Hutton's genius furnished by this Chapter is the manner in which he perceives the evidence for successive eruptions of igneous material. His generalization in this respect was far in advance of his time, and anticipated the conclusions reached by other observers of later generations. His statement in regard to the posteriority of the basalt-dykes may require a little modification. It is true that these dykes may be seen traversing both the granite and the basic sills; but there are acid intrusions which cut basic dykes and are not pierced by any. The basic dykes may, perhaps, as a whole, mark the latest phase of eruptivity, but their uprise must have extended over a long period, for some of them are certainly older than the granite, and others are older than the felsites and porphyries.]

† [The pitchstone for which Arran has long been famous was here noticed for the first time by Hutton. It is extremely interesting to observe that he at once recognised it as a natural glass, when on the continent and in this country mineralogists actually regarded it as

dark and not always of the same colour, being sometimes greenish, sometimes blackish; and though it has not any great degree of transparency, this is evidently owing more to an obfuscating substance than to the imperfect vitrification of this natural glass. Some of those glass-massès have also this particularity, which still confirms their vitreous nature; it is an appearance of a fibrous substance floating in the transparent mass; and is no other than a crystallization of some of the materials. An appearance similar to this is always found in our common glass-house pots, when the green bottle glass is not perfectly vitrified by sufficient fusion, or when it has undergone some change in cooling.*

This glass of Arran would appear to be

a chemical precipitate from water. Not only did he correctly detect its origin, but he accurately defined the cause of its opacity and noticed the "fibrous substance" (microlites of hornblende) floating in it, which he regarded as a crystallization of some of the constituents of the mass, and compared with the products of a glass-house.]

* [The last nine words of this paragraph have been added to the MS. in Hutton's own handwriting.]

nearly allied to the petuntze substance, but much more fusible. With the blowpipe, it melts into a colourless transparent body, with some bubbles; and the petuntze may be brought to this state also, but requires a greater degree of heat. Now to confirm this alleged affinity between the glass and the petuntze, I have specimens from Arran which would seem, both from their external appearance and the trial with the blowpipe, to be of an intermediate species, more fusible than the petuntze, and less so than the glass.

But besides the chymical nature of this glassy substance, there is another appearance which many of those bodies present, an appearance which still more approaches them to the nature of petuntze, with which we have compared them; this is that of being a perfect porphyry.* In this case, the ground of the mass is glass, and the maculæ felt-spath and quartz or crystal. Very remarkable specimens of this sort are found upon

* [Hutton's observation that the pitchstones are intimately linked with the felsites and porphyries has been verified by later researches.]

the surface in going up the hill to Goatfield; but I did not see the body or mass from whence they had been detached.

The glass now described is found in mass within the porphyry district; and there it is found also on both sides of the island. It might therefore with great propriety be included among the porphyries, as having like them, most commonly some white spots of felt-spath or quartz floating in the mass, to justify the character. But the glassy nature of this body, on the one hand, and its connection in some places with the whinstone on the other, inclined me to keep it thus distinct from both, and give it as a peculiarity of the island of Arran in general, although all that I have seen of this substance in mass has been in the porphyry district.

Whether we consider this glassy substance as a porphyry or a whinstone, the shape in which it is found among the strata equally corresponds to each of those two invading bodies, and is not different from what is found both in the porphyries and whinstones. Along the south side of Brodowick Bay

this glassy substance is found in great beds running between the strata; whereas on the other side of that ridge which separates the two bays of Brodowick and Lamlass, I found it contained within a whinstone dyke, upon the shore on the north side of Lamlass Bay; the glass here terminates at one end among the whinstone in shape of a wedge. But on the west side of the island, upon the shore at Kingscove,* I found it traversing the strata in great dykes; sometimes it is contained in the same dyke with a whinstone, alongside of which it runs; sometimes again the glass dyke was traversed by one of petuntze. This last case I saw there in a glass dyke of great thickness; and it is here remarkable, that, the glass dyke being distinctly traversed by that of the porphyry, this last must appear to be of the latest date or last operation, in like manner as the whinstone

* [Of these now celebrated pitchstone veins of Tormore, Arran, first noticed by Hutton, the earliest published account, illustrated with a plan, was given by Jameson (*Mineralogical Travels*, vol. i, p. 102). They have been since then frequently visited and described by later generations of geologists.]

dykes had appeared to be from the observations made at the south end of the island.

From Mr. Mills' description of what he observed in the islands of Mull, Jura, Iona, and Ilay [Islay], published in the *Philosophical Transactions of the Royal Society of London*, Vol. 80,* I will now trace the similarity that is to be found between those islands and the island of Arran, of which I have given the mineral history.

It appears that those islands are chiefly composed of alpine schistus; and that these ancient stratified masses have been invaded by granite and whinstone or subterraneous lava. Here it would appear that the last of these invasions is the whinstone, the granite being found here intersected by the whinstone dykes, as I found it in the island of Arran. It would also appear that those

* ["Some account of the Strata and Volcanic Appearances in the north of Ireland and Western Islands of Scotland. In two Letters from Abraham Mills, Esq., to John Lloyd, Esq., F.R.S." Read January 21, 1790, *Phil. Trans.* lxxx, pp. 73-100. This part of the present Chapter must have been added some years after the first part was written.]

whinstone invasions had been sometimes accompanied with a vitreous substance, of which Arran affords the most remarkable examples.

Here are also marks of marl, coal, and sandstone strata, upon the coasts of those islands as at Arran, only here the portions of these softer strata which are left would seem to be very small. The bed of coal intermixed with shale or bituminous schistus, which Mr. Mills found perfectly included in whinstone, upon the coast of Loch Leven [Scridain] in the island of Mull, is curious and interesting, for though dykes of whinstone often traverse the coal strata, and though I have found coal and bitumen in small quantities mixed or included in whinstone, an entire stratum thus included, has never been described, so far as I know. I have been informed by Mr. Raspe that there is another coal of the same kind, that is, coal under whinstone upon the south coast of the same island.*

* [The rocks of Islay and Jura mainly belong to the crystalline schist series of the Scottish Highlands, and include no marl, coal or sandstone. In Islay and

From these letters of Mr. Mills, it will also appear evident that those greater islands, which had been separated from the main-land, have their subordinate islands, which had been separated from them; and that the insulated rocks upon the coast are nothing but the fragments of hard and solid masses which had been destroyed by the sea gradually incroaching upon the land.

Besides the mineral history of the island

still more markedly in Iona there is a prolongation of the Lewisian gneiss with probably some of the Torridon sandstone. Mull, on the other hand, while it includes some ancient schists and granite on its south-western borders, is mainly built up of volcanic masses of older Tertiary age. The coal referred to in the text is found in lenticular seams between the basaltic lavas.

The Mr. Raspe above referred to had an eventful history. Born in Hanover (1737), he wrote on mineralogical and geological subjects, was charged with peculation, escaped from prison to England, obtained some mining employment in Cornwall, travelled over England and Scotland searching for possible mines, and finally died while on some similar journey in Ireland. He wrote and published anonymously the well-known *Adventures of Baron Munchausen*, and he is said to have been the prototype of Dousterswivel, Scott's "tramping philosopher," referred to in the note on p. 196.]

of Arran which has now been given, I have an observation to make with regard to the operation of the sea beating upon the shore, and wearing away the land which had taken its origin at the bottom of that very mass of water. It is not that any sort of dubiety occurs with regard to those operations by which the land is constantly diminishing, from the influences of the atmosphere and sea; it is not that examples of those operations are rarely to be met with, as may be the case with respect to the natural history of granite. A person who would study nature in the operations of the Globe, and see the actual dissolution of the solid land, has but to visit the coast of any country, and examine the rocks upon the shore. But every person is not qualified to read that book of nature; and there are many learned in the theory of the Earth who have not the opportunity of studying those operations of the sea upon the coast. It is for these that I would now give an example which occurs upon the coast of Arran; an example of that kind which though it may not be so singular as to merit



any particular attention, is distinct enough to afford a proper subject for description.

We have already seen that the south end of the island of Arran is composed of horizontal strata of marl and sandstone, with beds of interjected whinstone placed also horizontally among those strata. The island is here, I suppose, some hundred feet high, and all of similar construction, from the summit to the shore, declining all the way by steps in which the broken faces of those strata and beds of whinstone are to be observed. Upon the coast at one place there is a little plain or step above the sea; it is formed of a bed of whinstone immediately above the soil; and that bed of whinstone is of a peculiar nature, much approaching to petuntze. This flat rock, on which the old castle of Kildonan stands, presents its broken face upon the shore; and at the distance of a mile perhaps, or more, a portion of this rock on the same level, forms the island of Pladda, showing the same appearance as the other upon the coast of Arran.* It is evident that all the height of

* [It is very doubtful if the basic sill of Pladda is

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the island of Arran, or level masses above the plain on the coast, had been dissolved and washed away in the course of time; and now we may carry our views of those destructive operations still farther by considering Pladda as having been part of the low plain upon the coast of Arran. It is formed of the same horizontal mass of whinstone, which is superincumbent upon similar marly and sandstone strata, and upon which there had been formerly resting an immense mass of similar materials. It is thus, in seeing the former state of things that we are led to see the present with a scientific eye; and we shall investigate the natural operations of the earth for a space of time that will astonish in proportion as it is perceived.

The low flat island of Pladda had formed part of the high island of Arran; no proposition in natural history, concerning what is past, is more certain. The island of Arran had been extended beyond Pladda. But

the same as that of Kildonan. But the evidence of stupendous denudation in the south of Arran is none the less impressive.]

how far are we to go? Might we suppose the rock of Elza (Ailsa), that stupendous mass, to have been also part of Arran? This rock is a mass of granite-porphyry, and there is also whinstone mixed in that mass: this I have only from information and from specimens, having never been upon that singular island. If we shall now suppose the softer strata of marl and sandstone of Arran, which had extended far into the sea and among which the porphyry mass of Elza had been injected, in like manner as the Holy Island is at Lamlass, to be worn and washed away in the natural operations of the atmosphere and sea, the solid mass of Elza would remain a monument of what had been in Arran; while the little island of Pladda is the intermediate step by which we may remount to this view of high antiquity.*

By thus ascertaining the first step in our

* [The fine-grained granitic mass of Ailsa Craig is distinguished by the presence of riebeckite, a mineral also found in the granophyre of Skye. But there is no direct proof that the rock belongs to the same Tertiary series as the eruptive rocks of Arran, though such may not improbably be its age.]

cosmological speculation, we advance with some degree of certainty into the annals of a continent which does not now appear; and in tracing those operations which are past, we foresee distant events in the course of things. We see the destruction of a high island in the formation of a low one; and from those portions of the high land or continent which remain as yet upon the coast and in the sea, we may perceive the future destruction, not of the little island only, which has been saved from the wreck of so much land, but also of the continent itself, which is in time to disappear. Thus Pladda is to the island of Arran what Arran is to the island of Britain, and what the island of Britain is to the continent of Europe.

To give in one view the general doctrine of this Chapter. It must appear that the island of Arran was originally composed of stratified bodies, in which two species may be distinguished; on the one hand, the alpine schistus, much changed by fusion from its original state, and containing no visible mark of organized bodies; and on the other, strata

probably of later formation, less changed by fusion, and containing marks of organized bodies.*

That original mass of land, which we suppose to be at the bottom of the sea, was then broken and invaded by many different bodies in a state of fluidity or fusion ; such as granite, porphyry, petuntze, whinstone and glass. It also farther appears that these invasions had not all been made at one time ; but that some of them had succeeded others, and that among the latest of them all, are the perpendicular invasions (which we have termed dykes) of whinstone.

The highest or most alpine part of the island is formed of those invading bodies, this is granite ; while others of them appear only in form of perpendicular veins traversing the strata, and beds or floats [sills] interposed between them. But besides these two distinct appearances, of a great

* [Though he does not specially cite them, Hutton may have seen both the remains of plants in the sandstones and shales, and also of corals, crinoids, brachiopods and other organisms in the limestones of the Carboniferous series of Arran.]

granite district on the one hand, and the regular invasions of the strata on the other, there is every species and degree of these, or various compositions of those different modes of invasion to be found. Whatever, therefore, may have been the operation of subterraneous heat upon the unbroken stratified bodies, in procuring them solidity or hardness, the melting and elevating power of the mineral regions are manifested in the appearances of those invading bodies, of which so great a portion of the mass of Arran is composed.*

No idea can be formed of the shape of this island, when first proceeding from the bowels of the earth or bottom of the sea. Neither is it possible to say how much has been already worn away from the tops of the granite mountains; the points or peaks of

* [The most noticeable omission in Hutton's account of the geology of Arran is the absence of any reference to the raised beaches which form so striking a feature in the scenery of the island. The allusion on p. 40, and the fuller statement in vol. ii, p. 165 *et seq.*, show that he had recognized the less obtrusive evidence of upheaval on the east coast of Scotland.]

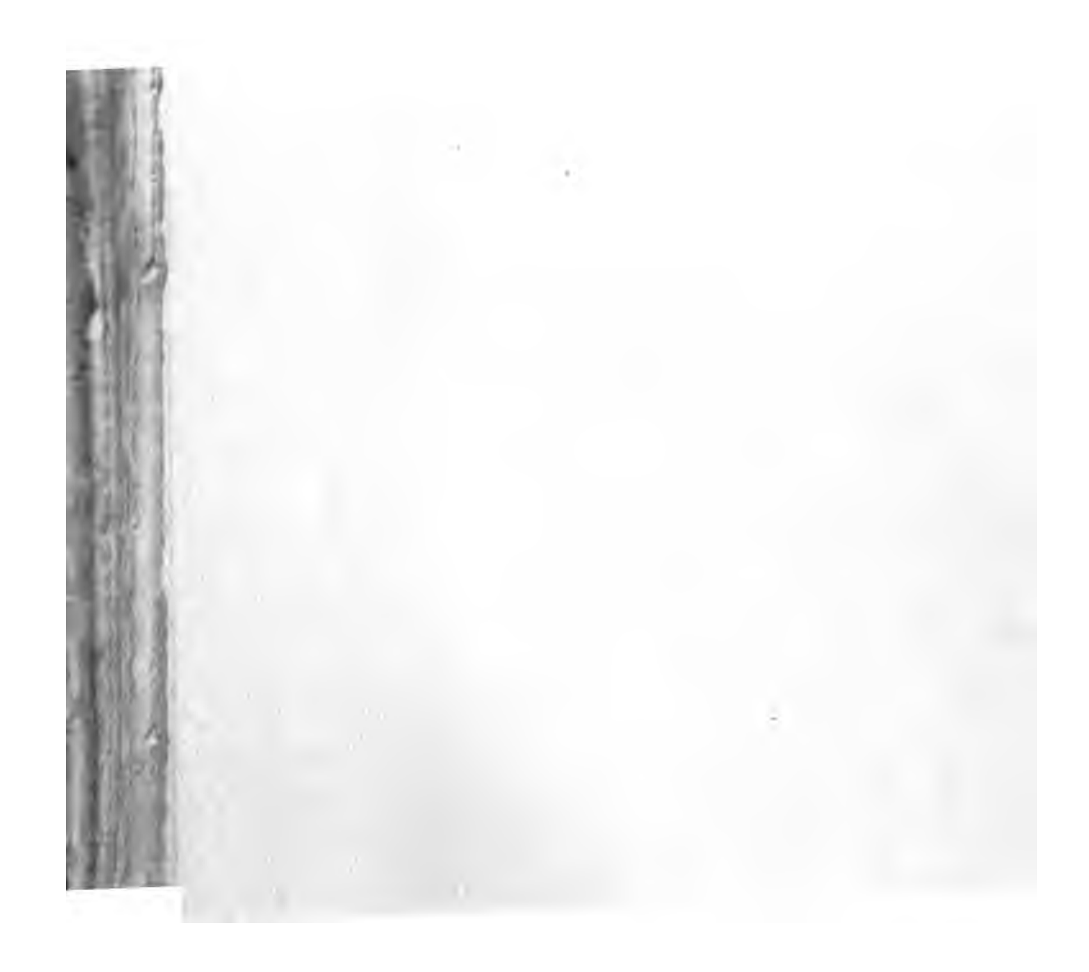
those lofty masses, and the thin ridges connecting the different mountains, all of which are visibly in decay, show that the thing we now perceive is only part of a greater mass which has subsisted once above them. This, however, we may with confidence aver, from the nature of the thing which now subsists, that all those valleys which intervene between those decaying mountains had been hollowed out of the solid rock by the hands of Nature operating for the purpose of this world, or in the course of time, by causes which continue to produce the same effect. But while so much of the solid granite has thus been made to disappear, how much of the softer strata may have undergone a similar fate ?

The great number of whinstone dykes upon the west coast in the shire of Ayr, opposite Arran, *i.e.*, from Scalmorly [Skelmorlie] almost to Irwin [Irvine] similar to those which we find in that island, give reason to conclude that these are continued under ground, or that they had proceeded originally from one mass. We thus are led to believe that the island of Arran and the

shire of Ayr had been raised from the bottom of the sea at the same time, or in the operation of the same causes; and that therefore those two coasts were once continuous land, which was afterwards preyed upon by the water, and disjoined by the sea. I doubt not but the same conclusion with regard to the former junction of this island and Kintyre may be made from the proper inspection of that coast, which I have not had an opportunity of doing.

Thus the Theory of the Earth, so far as founded upon the necessary destruction of the solid land above the level of the sea, and the interchanging of sea and land, will receive that support, from the particular examination of this coast of Scotland, which it has from the general survey of all the coasts upon the globe. In like manner, so far as there is every reason to attribute to the operation of heat and fusion, the consolidation of the original strata of loose materials which compose the island of Arran; and so far as the great invasions of those strata from below, by matter in the fluid state of fusion, gives reason to conclude that the bottom of

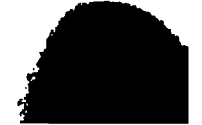
the sea had been thus raised above the level of its surface, the Theory of the Earth, founded upon those principles, is confirmed from the natural history of Arran.



INDEX.

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INDEX TO VOLS. I. AND II.

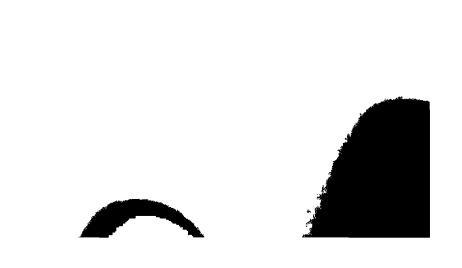




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